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Environmental Assessment of the At-Sea Incineration of Liquid Silvex

TRW Environmental Engineering Div.
Research Triangle Park, NC

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by

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ABSTRACT

This document is a preliminary environmental assessment of disposal of suspended liquid silvex herbicide formulations. Several alternative means of disposal, including no action, were evaluated. This evaluation led to selecting at-sea incineration onboard a chemical waste incinerator ship as the preferred alternative disposal action. The other alternatives were rejected because of undeveloped technology, adverse environmental impacts, high cost, or excessive disposal duration.

The analyses presented in this environmental assessment show that potential environmental impacts of the preferred and principal alternative disposal actions will be insignificant and transient. Impacts of potential accidents and malfunctions were considered, and means of mitigation are discussed.

This report is submitted in partial fulfillment of Contract No. 68-02-3174, Work Assignment No. 2, by TRW, Inc., Environmental Engineering Division under the sponsorship of the U.S. Environmental Protection Agency. This report covers work performed during the period 16 November 1979 to 13 May 1980.

SUMMARY

ORGANIZATION OF THE ENVIRONMENTAL ASSESSMENT

This preliminary environmental assessment of the disposal of liquid silvex herbicides is comprised of six major sections and six appendices, as well as an abstract and summary.

Chapter 1 presents a brief introduction, states the purpose of action, and states the need for action. EPA is required by law to take action.

Chapter 2 describes and evaluates 10 alternative actions, including the no action alternative. The preferred alternative is at-sea incineration; the principal alternative is land-based incineration. The other alternatives were rejected because of undeveloped technology, adverse environmental impacts, high cost, or excessive duration of the disposal action.

Chapter 3 describes the environment affected by the proposed and principal alternative disposal actions. Descriptions are given of meteorological, hydrological, geographical, and biological conditions in the areas where the proposed action would take place.

Chapter 4 presents an analysis of the environmental impacts of the proposed and principal alternative actions. The analyses are based on descriptions of the actions presented in Chapter 2 and the affected environment given in Chapter 3.

Chapters 5 and 6 present, respectively, the qualifications and roles of the preparers and References. Appendices A through E present: A) characterization of the liquid silvex formulations, B) summaries of other pertinent incineration programs, C) transportation requirements, D) a description of the M/T Vulcanus, the larger and more extensively tested of two currently operational chemical waste incinerator ships, E) details and results of plume dispersion modeling and other calculations, and F) calculations of scrubber water quality.

PROPOSED ACTION

At-sea incineration is the preferred alternative action based on results of the environmental analyses, cost estimates, and technology evaluations prepared for this environmental assessment.

The proposed action is comprised of five discrete tasks: decanning the liquid silvex formulations, transporting the bulk material to the ship loading dock, ship loading, at-sea incineration, and ship cleaning. Each of these tasks is described in sufficient detail in Chapter 2 so that the environmental impacts can be determined.

Decanning

An estimated 1.2 million gallons of liquid silvex formulations in about 4.7 million containers require disposal. Perhaps 100 containers are larger than one gallon. For decanning, unopened containers will be fed by conveyor or forklift to a high-torque, low-speed shear-type shredder. Herbicide released into the shredder will be piped to on-site storage. Wet scrap will be rinsed or incinerated to conform with EPA regulations and will be landfilled or recycled.

Decanning will be performed in an existing or temporary facility. This facility will have a ventilation system capable of reducing vapors below occupational health hazard levels. Vapors will be vented through activated charcoal absorbers or directly into an operating on-site incinerator.

Extensive monitoring will be performed both within and outside the facility.

Transportation to the Loading Site

Selection of the mode of transportation of the decanned liquid silvex will be made after a suitable decanning facility is selected. Three modes are considered: pipeline, rail tank cars, and tank truck. Evaluations of each mode are presented.

Ship Loading

Ship loading will require a land-based pumping system. Measures for controlling and mitigating consequences of potential spills are described.

At-Sea Incineration

A suitable incinerator ship has not yet been selected. However, owing to extensive past testing on the M/T Vulcanus, this ship is used in this environmental assessment as an example. The amount of herbicide requiring disposal and the size of the ship dictate that two burns be scheduled. Burns will take place within one of two designated at-sea incineration sites.

During incineration operations, extensive stack sampling, monitoring, and analysis activities are planned to assure that permit requirements are met and that environmental impacts are minimized.

Ship Cleaning

After completion of incineration operations, the ship's tanks will be cleaned of residual herbicide by replicate serial rinsing with kerosene or diesel fuel. Ship cleaning will take place in the designated incineration site. Tank rinsate will also be incinerated within the site.

MAJOR ALTERNATIVES

Land-Based Incineration

Land-based incineration is considered the principal alternative to at-sea incineration. The technology for land-based incineration is as well developed as that for at-sea incineration and better developed than those of any other alternative except secure landfilling. Land-based incineration was ranked lower than at-sea incineration because it presents the possibility of greater environmental impacts, would take considerably longer, and would cost more than at-sea incineration.

Secure Landfilling

The technological basis of secure landfilling is reasonably well developed although still growing. Secure landfilling was rejected as the proposed or principal alternative action because of the potentially greater long-term environmental impacts and considerably greater cost than the at-sea or land-based incineration alternatives. Landfilling would only postpone the problem to future generations when the drums containing liquid silvex containers eventually corrode, exposing the metal containers to eventual corrosion and release of the silvex into the landfill site and, potentially, into the surrounding environment. Proposed RCRA regulations do not categorically ban landfilling of liquid wastes. However, they would require that containers of liquid wastes be surrounded by sufficient sorbent material to absorb all the liquid waste and that bulk liquids be treated to a nonflowing consistency.

Return to Manufacturers for Reprocessing

Three potential reprocessing methods were considered: photolysis, chlorinolysis and fractionation. Photolytic dechlorination of the 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) contaminant in silvex formulations by ultraviolet radiation would be a most satisfactory disposal method because after destruction of the TCDD, the liquid silvex stocks could be used for the purpose originally intended. However, this technique is currently performed on a laboratory scale only. No facility exists which is capable of handling the volume of liquid silvex involved. The engineering, test, and environmental studies and the cost and time lag needed to implement photolysis as a disposal alternative led to its rejection.

Chlorinolysis is a process for converting organochlorine compounds to perchloroethylene, trichloroethylene, and carbon tetrachloride, all of which have definite, but variable commercial value. The process is practiced on a small scale in the United States and on a large scale in Germany. Chlorinolysis was rejected as a disposal alternative because, at the current state of technological development, it does not convert aromatic compounds and does not work when the sulfur content of a waste exceeds 25 parts per million (ppm). The active ingredients of these formulations are aromatic compounds, and their sulfur content is of the order of 3000 ppm.

Fractionation by distillation offers the attractive benefits of recovering the kerosene carrier of these formulations and of reducing the volume of herbicide to be disposed of. Fractionation by means of adsorbing the TCDD contaminant on a material such as activated charcoal offers even more attractive benefits of returning these formulations to their intended use as herbicides. The U.S. Air Force tested both of these techniques for disposing of TCDD-contaminated Herbicide Orange and found both methods unsatisfactory. Distillation might be satisfactory for liquid silvex because the kerosene carrier is orders of magnitude more volatile than the active ingredients. However, the studies and facilities necessary to implement this alternative are considered to be prohibitively costly and time consuming. Charcoal adsorption would produce a huge volume of TCDD-contaminated charcoal. Since ultimate disposal of this contaminated charcoal would require land-based incineration or secure landfilling, this alternative was also rejected.

Sludge Burial and Microbial Reduction

Both of these techniques are variants of landfilling. Both involve placing opened containers in the earth and surrounding them with activated sludge or specially-developed microbes to degrade the formulation. Both were rejected as disposal alternatives because of unproved technology, uncertain environmental impacts and costs, and the many years required for complete destruction of the herbicide.

AFFECTED ENVIRONMENT

At-Sea Incineration

In general, the sea is well suited to receive the exhaust from incinerator ships which efficiently burn organochlorine wastes. The chlorine content, moderate basicity, and high buffering capacity of the sea readily absorb the HCl emissions from the incinerator stack. With destruction efficiencies in excess of 99.9 percent and the wide dispersal of the exhaust plume, impacts of the 0.1 percent of unburned wastes are minimized.

It is proposed to incinerate the liquid silvex formulations in either the Gulf Coast or North Atlantic incineration sites. The Gulf Coast site is presently designated for at-sea incineration of organochlorine wastes; the North Atlantic site is currently in the process of being designated.

As described in Chapter 3, both of these sites are: 1) more than 100 miles from the nearest land mass, 2) of recognized low biological production, 3) not used for commercial fishing or recreation, and 4) far from shipping lanes. These characteristics, coupled with the physicochemical characteristics described above, make these selected marine environments suitable for at-sea incineration. Of the two sites, the Gulf Coast is preferred because of warmer temperatures, lower wind speeds, and lower wave heights.

Land-Based Incineration

A candidate site for land-based incineration has not yet been selected; consequently, neither here nor in Chapter 3 can details on the affected environment be given. A typical facility was used for modeling purposes. In general, commercial land-based incineration facilities are located in industrialized areas with relatively low population densities in the immediate area. Biological productivity is also relatively low near these sites. If this alternative were to be implemented, the site selected will require a wet scrubber to control HCl emissions. Disposal of the liquid stream from the scrubber is expected to pose the greatest problem and potential for environmental impact.

ENVIRONMENTAL CONSEQUENCES

At-Sea Incineration

Impacts on air quality are expected to be minimal. Vapor control methods planned for decanning, transportation, and ship loading operations will result in zero or minimal release of liquid silvex vapors, producing minimal effects. A monitoring program will be performed to verify attainment of the required destruction efficiency. At-sea incineration results in the release of large amounts of CO_2, water, HCl, particulates, and heat. Despite the high efficiency of the incineration process, kilogram quantities per hour of unburned herbicide components will be released. However, because of the enormous dilution of the incinerator plume in air, impacts are expected to be minimal. The marine environment will readily absorb the heat, CO_2, water, HCl, and particulates emitted. As will be shown in Chapter 4, maximum air concentrations in the plume downwind of the ship are near state-of-the-art analytical detection limits.

Impacts of stack emissions on water quality are expected to be minimal. Because of the required high destruction efficiency (greater than or equal to 99.9 percent) and the enormous dispersal of the plume prior to touchdown on the ocean, tremendous dilution of unburned herbicide component will occur. Concentrations of the liquid silvex esters will be of the order of nanograms (10^{-9} g) per liter (parts per trillion) before their rapid hydrolysis to the less toxic acids. Concentration of TCDD will be on the order of femtograms

(10^{-15} g) per liter (parts per quintillion), well below levels known to cause adverse effects. Increases in chloride content are expected to be of the order of 0.1 percent and pH change below 0.2 pH units. These changes will be minimal, transient, and localized.

Effects on marine flora and fauna in the incineration site are expected to be minimal and transient. Results of plume modeling combined with toxicological data indicate that sea water concentrations of unburned herbicide components will be orders of magnitude below levels at which toxic effects have been observed.

Incinerator malfunction, wind speed or direction shifts which cause the plume to settle on the ship, and accidents all have potential to cause harm to the ship's crew. However, none of these potential hazards has caused problems during the extensive use of at-sea incineration vessels in U.S. and European waters. Incinerator ships are built with mandatory control devices which stop waste feed in the event of incinerator malfunction. The impacts of total cargo loss from collision or sinking are potentially great and essentially unquantifiable. The probability of either occurrence is exceedingly low, and incinerator vessels are constructed (double hull, double bottom) so as to reduce spills in the event of collision.

Land-Based Incineration

Impacts on air quality from decanning and transportation operations for the land-based alternative are expected to be minimal. The operations themselves will be similar to those for the at-sea incineration alternative, as will be the means of vapor control.

Impacts on air quality from land-based incineration operations will be minimal. Destruction efficiency will be at least 99.9 percent. The wet scrubber will remove at least 99 percent of emissions of HCl and particulates. The low emission rates of organochlorine compounds means they will also be scrubbed efficiently. Neutralization of the used scrubber water will rapidly hydrolyze unburned herbicide esters. Plume dispersion modeling indicates a maximum downwind HCl concentration of 0.6 $\mu g/m^3$, well below the 7 mg/m^3 value considered safe for occupational exposure.

Impacts on water quality resulting from disposal of the spent scrubber water may be substantial depending on the mode of disposal at the candidate facility. Spent scrubber water will have high loadings of solids, inorganic chlorides, and possibly organochlorine compounds, which make direct discharge undesirable. Treatment prior to discharge is therefore desirable, and water quality impacts will thus depend on the treatment method at the facility.

Impacts on soil, flora, and fauna would be expected to be minimal. Slight soil acidification from HCl emissions might occur. Emissions of unburned herbicide components will be so low as to cause adverse effects only on very sensitive plants near the facility.

Generally speaking, impacts of accidents and malfunctions are potentially greater for land-based than for at-sea incineration. Incinerator feed rates are typically one-third to one-fourth those of incinerator ships, requiring a three to four times longer disposal operation. There are more process operations involved; thus, a greater potential for equipment malfunction exists. However, proper contingency planning and placement of emergency equipment can reduce the risks of potential accidents and malfunctions to a minimal level.

RECOMMENDATIONS

It is recommended that the preferred alternative of at-sea incineration be implemented. It is further recommended that plans as detailed as those prepared by the U.S. Air Force and its contractors for the disposal of Herbicide Orange be prepared for: 1) at-sea and land-based sampling, monitoring, and analysis, 2) operations, 3) contingencies, and 4) health and safety and that these plans become part of the final environmental assessment and permit.

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Mrs. Beth Riley and Mr. Ron Korner of TRW assisted in preparing appendices A, B, and D.

1. PURPOSE OF AND NEED FOR ACTION

Incineration at sea by specially designed incinerator vessels has been shown to be a most effective means of disposing of toxic chemical wastes. Such incinerations have also been shown to be environmentally acceptable and cost effective. It has been proposed to incinerate at sea stocks of liquid silvex herbicides. This environmental assessment (EA) describes the proposed action, alternatives to the proposed action, and probable environmental impacts. Chapter 1 provides background information, describes the purpose of and need for action, and discusses pertinent Federal laws and regulations.

1.1 INTRODUCTION

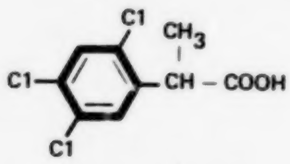
On 28 February 1979, the Administrator of the U.S. Environmental Protection Agency (EPA) signed an emergency order suspending registrations of home and garden, forestry, rights-of-way, commercial/ornamental turf, aquatic weed control/ditch bank and pasture uses of pesticides containing silvex and issued a notice of intent to cancel registrations of silvex containing pesticides for these uses because he found (1) that these uses posed an imminent hazard to humans and the environment. At the same time, the EPA Office of Enforcement issued orders to prevent the sale or distribution of the suspended products.

On 7 May 1979, Chevron Chemical Company signed an agreement with EPA which settled all disputes concerning the company's suspended home and garden products. Since that time, similar agreements have been signed with 16 other Registrants. One provision of the agreements is that EPA, as required by Section 19 of the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), accept for disposal the cancelled silvex products collected by the Registrants. A second provision of the Agreements is the Registrants store the recalled product until EPA designates disposal sites at which the agency will accept the products.

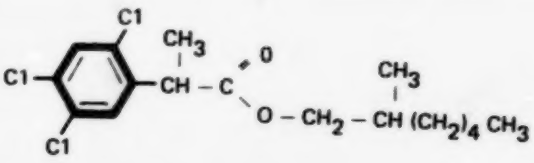
EPA has created a Silvex Disposal Task Force to oversee the disposal operation. The initial recommendation of the Task Force was to dispose of the liquid silvex products by incineration at sea.

EPA contracted (Contract No. 68-02-3174, Task Order No. 2) to have a draft operating plan and guidelines document (3) and a preliminary environmental assessment prepared for the at-sea incineration of the liquid silvex herbicide formulations. This document therefore assesses the environmental impacts of the proposed disposal of suspended liquid silvex products for home and garden uses.

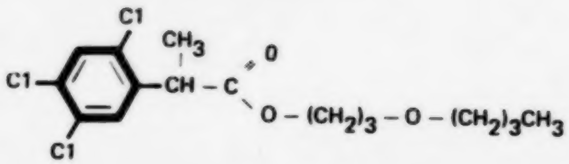
Liquid silvex is used in this environmental impact statement to refer generically to the various product formulations which were suspended by EPA. Silvex itself is 2-(2,4,5-trichlorophenoxy) propionic acid (2,4,5-TP,I). Two different esters of silvex are actually used in the liquid product formulations: the isocytl ester (II) and the butoxypropyl ester (III). Several of the formulations also contain the butoxypropyl or isoctyl esters of 2,4-dichlorophenoxy acetic acid (2,4-D, IV). The formulations contain from 56 to 87 percent inert ingredients, chiefly light petroleum distillates, such as kerosene.



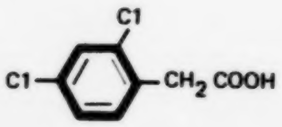
I. SILVEX (2,4,5-TP)



II. SILVEX, ISOOCTYL ESTER



III. SILVEX, BUTOXY PROPYL ESTER



IV. 2,4-DICHLOROPHENOXY ACETIC ACID (2,4-D)

An unavoidable side reaction in the synthesis of silvex produces the highly toxic compound 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD). Careful control of reaction conditions minimizes the amount of TCDD produced, but all silvex and related herbicides will still contain some TCDD. Information available (1) to the Administrator of EPA led to the emergency suspension of registrations of herbicides based on 2,4,5-trichlorophenoxyacetic acid (2,4,5-T). Because both silvex and 2,4,5-T are contaminated with TCDD and because of similarities between the two herbicides in chemical structure, manufacturing processes, use patterns, and effects in experimental systems, the Administrator of EPA suspended and cancelled registrations of several uses of silvex and initiated this disposal action (1).

Appendix A presents a description of the physical and chemical characterization of the suspended formulations and their TCDD content. In summary, the average composition of the liquid silvex to be incinerated is:

- 0.6 percent isoctyl ester of silvex
- 9.6 percent butoxypropyl ester of silvex
- 0.1 percent isoctyl ester of 2,4-D
- 20.4 percent butoxypropyl ester of 2,4-D
- 69.3 percent inert ingredients, principally kerosene
- 2×10^{-6} percent TCDD

It is estimated that 1.2 million gallons of liquid silvex herbicide will be collected. This volume of silvex contains 82 g (0.18 pounds) of TCDD. With a destruction efficiency of 99.9 percent, approximately 82 mg (0.00018 pound) of TCDD would be emitted to the atmosphere during the incineration action. The maximum resulting concentration of TCDD at the sea surface is estimated to be 0.011 pg/m^3 (1 pg = 10^{-12} g), very close to the state-of-the-art limits of detection and several orders of magnitude below maximum permissible levels based upon continuous exposure.

1.2 PURPOSE OF ACTION

The purpose of action is to dispose of collected stocks of liquid silvex in a safe and environmentally acceptable manner. It is proposed to dispose of the liquid silvex by incineration at sea onboard a chemical waste incinerator ship. The scope of this disposal program and of this environmental assessment includes all necessary tasks leading up to incinerating the liquid silvex, the incineration, and cleaning the ship after the incineration.

The Vulcanus and the Vesta are currently the only operating chemical waste incinerator ships which are ocean going and meet all London Dumping Convention requirements. The Vulcanus is chartered by Ocean Combustion Services, B.V., of the Netherlands and has a capacity of approximately 3,500 tonnes. Because of the extensive previous testing on the Vulcanus, this ship is discussed further in this environmental assessment. The Vesta is owned and operated by Linkering, A.G. of West Germany, and has a capacity of approximately 2,160 tonnes.

1.3 NEED FOR ACTION

Under Section 19 of FIFRA, EPA must accept and dispose of stocks of liquid silvex accumulated and currently stored by the Registrants as a result of the emergency order (1). Therefore, action is necessary so that EPA can dispose of the large volume of accumulated liquid silvex.

1.4 FEDERAL LEGISLATION AND CONTROL PROGRAMS

This section presents a general discussion of Federal laws and regulations pertinent to the proposed action.

1.4.1 Federal Insecticide, Fungicide, and Rodenticide Act, as Amended (FIFRA)

Under Section 6 of FIFRA, the Administrator is required to cancel the registration or change the classification of a pesticide whenever he determines that the pesticide no longer satisfies the statutory standard for registration. Section 6(c) of FIFRA also provides suspension provisions so that the Administrator may take rapid, interim action until final cancellation decisions in cases involving imminent hazards to man or the environment.

Under Section 19 of FIFRA, EPA is required to accept and dispose of herbicide suspended and cancelled because of imminent hazards, if requested by the owners of the products. EPA has signed agreements with seven Registrants of liquid silvex products in order to regularize this process. It is estimated (2) that approximately 1.2 million gallons of silvex herbicides will be collected.

A 1972 amendment (P. L. 92-516) provides, among other things, definitive control of pesticide and pesticide container disposal and storage. Implementing regulations and recommended procedures for storage and disposal of pesticides and pesticide containers have been promulgated (40 CFR 165.1 - 165.11).

1.4.2 Resource Conservation and Recovery Act of 1976 (RCRA)

RCRA is intended to manage and control hazardous waste from its generation to its final disposal. The Silvex Disposal Task Force has determined that EPA and the disposal facility operator(s) will comply with any applicable regulations issued under RCRA.

Final and interim final RCRA regulations (40 CFR 261) classify the liquid silvex product formulations as hazardous because of their ignitability (flash point less than 60°C) and their silvex content (greater than 0.1 mg/l). These formulations are also designated as hazardous because of their TCDD content (a substance listed in Appendix VIII (45 FR 33133)).

Final RCRA regulations (40 CFR 261, 45 FR 33151) prescribe that hazardous wastes will be shipped in accordance with U.S. Department of Transportation (DOT) regulations (49 CFR 173, 178 and 179). The proposed implementing regulations also specify labeling requirements.

Final and interim final regulations (40 CFR 264, 265; 45 FR 33154) prescribe standards applicable to owners and operators of hazardous waste disposal facilities. These proposed standards include site selection, security, contingency plan and emergency procedures, training, record keeping, etc. Standards for storage of hazardous waste are also prescribed.

Ocean dumping activities are covered by the Marine Protection, Research and Sanctuaries Act (MPRSA). In addition, RCRA imposes reporting requirements on MPRSA which relate to transportation of the materials. At-sea incineration is adequately regulated by MPRSA which is briefly described in Section 1.4.4. Because of the adequacy of regulations promulgated under MPRSA and its interrelationship with the London Dumping Convention (Section 1.5), regulations developed under RCRA will not be used to control at-sea incineration. However, as mentioned above, RCRA will control land-based transport and storage of hazardous wastes permitted to be burned at sea.

1.4.3 Marine Protection, Research, and Sanctuaries Act of 1972, as Amended (MPRSA)

Regulations for incineration at sea established by the London Dumping Convention are implemented through MPRSA. MPRSA gives EPA the authority to regulate transport for purposes of ocean dumping through a permitting system. During 1974, EPA interpreted that incineration at sea comes under the regulatory requirements of MPRSA. Pursuant to MPRSA, EPA has promulgated regulations and criteria for ocean dumping and for designating sites for dumping (40 CFR 220 - 229).

EPA has established a permit program for ocean disposal. Applications for a permit may be filed with the Administrator or the appropriate Regional Administrator (Part 221). EPA must give public notice and allow opportunity for public hearing before issuing a permit (Part 222).

EPA issues five types of permits of ocean dumping: general, special, interim, emergency, and research (Section 220.3). Research or interim permits are issued for at-sea incineration until specific regulatory criteria have been promulgated (Section 220.3[f]). However, EPA special permits may be issued in cases where studies on the waste, the incineration method and vessel, and the site have been conducted and when the site has been designated for incineration at sea in accordance with the procedures of Section 228.4.

Section 228 gives the Administrator of EPA authority to designate recommended sites for ocean disposal. EPA voluntarily prepares environmental impact statements on designating ocean disposal sites. There is only one site designated for at-sea incineration and it is located in the Gulf of Mexico (4). Designating a site off the north Atlantic coast is being considered, and a draft EIS is being prepared (5).

1.4.4 Clean Water Act of 1977 (CWA)

The CWA amends the Federal Water Pollution Control Act of 1972. Section 311(c) (2) of the CWA gave the President of the United States the responsibility to issue a nationwide contingency plan for dealing with water pollution from oil and hazardous materials. By Executive Order 11735 (August 1973), the President delegated this responsibility to the Council on

Environmental Quality (CEQ). In 1973, CEQ published the National Oil and Hazardous Substances Contingency Plan (40 CFR 1510), hereinafter called the Plan. Final revisions are found in Federal Register, Vol. 45, No. 55, pp. 17832-17860, March 19, 1980.

The Plan is applicable to all Federal agencies and is effective for the navigable waters of the United States and adjoining shorelines, the contiguous zone, and the high seas beyond the contiguous zone in connection with activities under the Outer Continental Shelf Lands Act or the Deepwater Port Act of 1974, or which may affect natural resources belonging to or under the exclusive management of the United States (40 CFR 1510.3(a)).

Discharges permitted by Section 102 of MPRSA (i.e., permitted ocean dumping activities and at-sea incineration) are specifically exempted from conformance with the Plan (40 CFR 1510.5(f)). Consequently, the at-sea operations of the proposed action are exempted from conformance with the Plan.

Land-based operations of the proposed action are regulated under RCRA. The owner/operator of a waste handling/disposal facility is required to develop a contingency plan which must, as a minimum, follow provisions of Section 311 of the Clean Water Act of 1977 (40 CFR 250.43-3), which mandates preparation of the Plan.

While the land-based operations are not exempt and at-sea operations of the proposed action are exempt from conformance with the Plan, a contingency plan will be prepared for the entire proposed disposal action which will be in conformance with the Plan and will incorporate the key features: (1) notification, (2) evaluation, (3) containment and counter measures, (4) mitigation and disposal, and (5) documentation.

1.4.5 Occupational Safety and Health Act of 1970 (OSHA)

OSHA established the Occupational Safety and Health Administration within the U.S. Department of Labor and empowered this administration to promulgate regulations to protect workers from hazards in the work place. Pursuant to OSHA, regulations (29 CFR 1910.1000) have been established for various chemical compounds, including 2,4-D, 2,4,5-T, and several alkanes which are constituents of the kerosene carriers of the liquid silvex formulations.

2. ALTERNATIVES INCLUDING THE PROPOSED ACTION

As described in Section 1.3, EPA is committed by law (1) to accept and dispose of the cancelled products collected by the Registrants. EPA must accomplish this disposal in a safe manner without causing adverse environmental impacts.

Chapter 2 of this environmental assessment describes alternative disposal actions including the alternative of no action. The alternative actions are evaluated in terms of environmental impacts, state-of-the-art of technology, cost, and other pertinent factors.

The evaluations led to the selection of incineration at sea as the preferred disposal action and land-based incineration as the principal alternative disposal action, based on descriptions of the environment potentially affected (Chapter 3) and detailed analysis of environmental impacts (Chapter 4). Other alternatives evaluated include no action, reprocessing of the herbicide by photolysis, chlorinolysis and fractionation, secure landfills, sludge burial and microbial reduction.

2.1 NO ACTION ALTERNATIVE

Under Section 19 of FIFRA, EPA is committed to collect the suspended and cancelled liquid silvex formulations from the registrants and dispose of them. If no disposal action is taken, EPA may be required to arrange for storage at one or more federally designated depositories which will have to meet requirements imposed by recommended procedures written under FIFRA (40 CFR 165) and regulations written under RCRA (40 CFR 265). Even following regulations for long-term storage of pesticides, the metal containers will eventually deteriorate, and a major transfer operation to new containers will be necessary. Long-term storage and transfer operations will have potentially adverse environmental impacts and substantial cost. Taking no action is, therefore, not considered to be a viable alternative.

2.2 INCINERATION AT SEA

One of the two alternatives for disposal of liquid silvex formulations to be considered in detail in this section is at-sea incineration utilizing shipboard incinerators. In the sections that follow, operating details of the at-sea incineration option will be discussed, and the environmental impacts of both normal operations and potential accidents and malfunctions will be assessed.

2.2.1 Description of the Proposed Action

Incineration of liquid silvex formulations at sea is but a single step in the proposed disposal action. Separate operations which comprise the silvex disposal action have been defined: decanning, transportation to the ship loading site, ship loading, at-sea incineration, and ship cleaning. Figure 1 is a schematic diagram of the at-sea incineration option. In the following sections, the size and location of facilities required and the operation and maintenance of these facilities will be described. Estimates of schedules and costs associated with the at-sea incineration alternative will also be made.

2.2.1.1 Operations and Maintenance Requirements--

Detailed written plans of operation will be drafted for all phases of the at-sea incineration operation. Contingency plans incorporating the key elements of preparedness, prevention, emergency notification, and emergency procedures will be developed as required by applicable laws, regulations, and permits. A draft Operations Plan has been prepared (3).

2.2.1.1.1 Decanning--As a first step in the disposal action, millions of metal and glass containers of liquid silvex formulations must be drained and rinsed and their contents transferred to storage tanks. Unopened containers will be fed by conveyor to a high-torque, low-speed shear-type shredder. Herbicide from the drained containers will be collected for land-based storage, while the wet scrap will be rinsed to conform with EPA recommendations (40 CFR 165.9) and landfilled (40 CFR 265). Alternatively, wet metal scrap containers could be incinerated in an approved hazardous waste incinerator. Decanning system design is described in detail in References 3 and 7.

Because of the vapor pressure characteristics of the liquid silvex formulations (Appendix A), decanning will result in the release of kerosene, 2,4-D, 2,4,5-TP, and TCDD vapors. To prevent uncontrolled escape of these

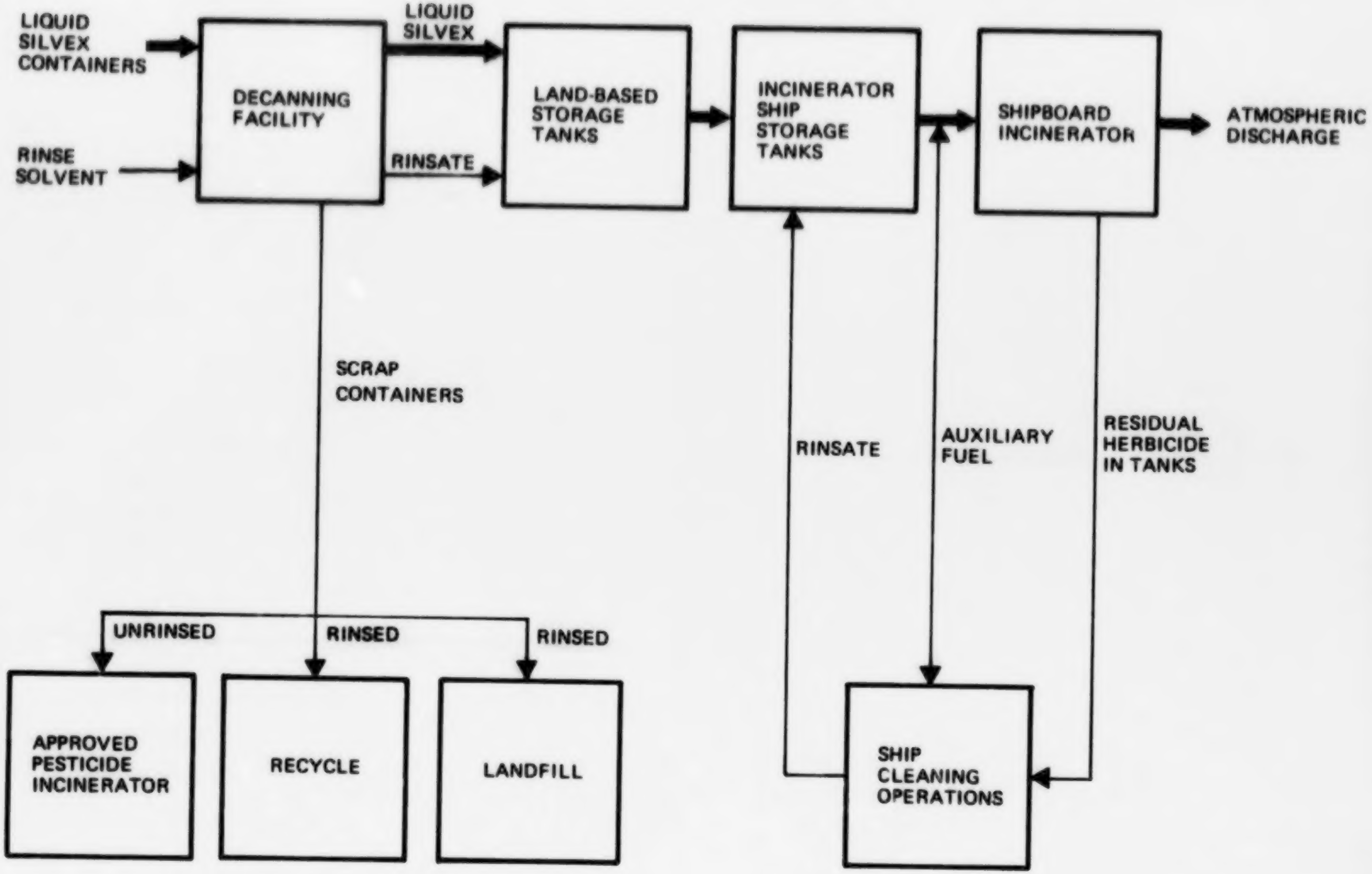

LIQUID SILVEX CONTAINERS
RINSE SOLVENT
DECANNING FACILITY
LIQUID SILVEX
RINSATE
LAND-BASED STORAGE TANKS
INCINERATOR SHIP STORAGE TANKS
SHIPBOARD INCINERATOR
ATMOSPHERIC DISCHARGE
SCRAP CONTAINERS
RINSATE
AUXILIARY FUEL
RESIDUAL HERBICIDE IN TANKS
UNRINSED
RINSED
RINSED
APPROVED PESTICIDE INCINERATOR
RECYCLE
LANDFILL
SHIP CLEANING OPERATIONS

Figure 1. Schematic diagram of at-sea incineration operations.

vapors to the atmosphere, decanning will be performed within an enclosed facility maintained at slightly subatmospheric pressure. Vapors from the facility will be exhausted through activated charcoal absorbers to the atmosphere. An alternative method of vapor control is to vent vapors directly into an operating, on-site chemical waste incinerator. Personnel safety will be maintained by use of effective safety equipment and procedures, as described in Reference 3, which also describes the extensive sampling and analysis program planned for decanning operations.

2.2.1.1.2 Transportation to ship loading site--The three modes considered for transport of decanned liquid silvex from land-based storage tanks to the incineration ship are pipeline, rail tank car, and tank truck. Selection of the mode of transportation to be used will be made after a suitable decanning facility has been identified. In general, the distance from decanning facility to ship loading area should be minimized. Pipeline transfer is the preferred method, since it will involve the least risk to public health and the environment. This mode would only be economically feasible, however, if a pipeline is already installed between the decanning facility and the ship loading dock. Transport by rail tank car is the next most favored method. This mode (8,10) was used in the disposal of Herbicide Orange by at-sea incineration (see Appendix B). Appropriate safety measures such as movement of tank cars at low speed (about 5 kilometers per hour) with guards at all crossing and absorbent materials nearby to contain spills would ensure safe transport. Tank trucks may be used for transfer of herbicide to the incinerator ship. Restriction of public access to the shipping route during transport would minimize the risk of public exposure to possible herbicide spills. Administrative and legal aspects of the transport operations are addressed in Appendix C. Reference 3 describes preliminary planning.

Decontamination of the transport equipment and vessels will require rinsing with water and/or kerosene, depending on the availability and cost of appropriate emulsifying agents. Details of the decontamination procedure are dependent upon the transport mode employed. A pipeline transport system would probably require the transport of several pipeline volumes of rinse to effect decontamination. Tank cars or tank trucks could be decontaminated by employing a triple rinse approach and spraying the interior of holding vessels with the rinse liquid. Such an approach would tend to minimize the quantity of rinse liquid required. Details of the decontamination procedures will be determined consistent with the selected mode of transportation and recommended procedures for disposal of herbicide containers, 40 CFR 165.9.

2.2.1.1.3 Ship loading--There are distinct areas of responsibility in shiploading operations: land-based and shipboard. Land-based shiploading operations include operating the land-based pumping system, connecting the pump system to the silvex transport pipeline/vehicle and monitoring the pump system for leaks during pumping operations. It is anticipated that responsibility for providing an appropriate land-based pump system and operating procedures will reside with either the decanning facility contractor or EPA. Shipboard operations include connecting the loading hose to the loading manifold, operating valves to load the various shipboard storage tanks, gauging the tanks and monitoring for shipboard leakage. Procedures for shipboard operations will be provided by the operator(s) of the incinerator ship. To ensure safe and efficient ship loading, close coordination between EPA, the decanning contractor, ship personnel, the monitoring contractor and other parties such as the U.S. Coast Guard will be necessary.

The risk of environmental contamination from a potential spill will be minimized by isolating the land-based pump(s) within a basin constructed with sand bags and lined with impermeable plastic. Flexible transfer hose will be used, with containers and absorbent material positioned to catch possible leaks at connections. Equipment like that for containing oil spills will be present on site for use in the event of a spill into water. Personnel safety procedures outlined in Reference 3 will ensure adequate protection of personnel involved with shiploading.

2.2.1.1.4 Incineration at sea--Incineration of the liquid silvex will be carried out onboard a chemical waste incinerator ship in a designated at-sea incineration site located either in the Gulf of Mexico or off the North East coast of the United States. A description of the M/T Vulcanus, the largest and most extensively tested incinerator ship presently in operation, is included in Appendix D. This incinerator ship is approved and certified under the regulations for incineration at sea. The incineration operations will be conducted in accordance with the recommended London Dumping Convention Technical Guidelines. Herbicide incineration will take place in the two shipboard incinerators after preheating to operating temperature by combustion of diesel fuel. Waste combustion with simultaneous stack gas monitoring will be carried out until all waste in the tanks is destroyed. Low ambient air temperatures during winter and spring in the North Atlantic may complicate or preclude stack gas monitoring during this period due to freezing of impinger solutions and problems associated with maintenance of required temperatures in sampling lines. The only waste stream from the incinerator is the stack gas which is released without treatment to the atmosphere. Further details of the incineration operating procedures and monitoring plan are described in Reference 3. Summaries of pertinent incineration programs are presented as Appendix B. References 11-16 provide details of past at-sea incineration programs, particularly the at-sea incineration of Herbicide Orange. References 17 and 18 are detailed sampling, monitoring, and analysis and health and safety plans for the at-sea incineration of Herbicide Orange.

Reference 3 describes the extensive onboard monitoring, sampling, and analysis program planned for this preferred action.

2.2.1.1.5 Ship cleaning--Residual herbicide remaining in the ship's tanks after incineration will be removed before the ship is allowed to enter port. Cleaning procedures will consist of serial rinsing of the ship's tanks and feed lines with kerosene or diesel oil, followed by at-sea incineration of the rinsate. Verification of the adequacy of the cleaning will be made by sampling residual liquid in the tanks and analyzing for TCDD.

2.2.1.2 Size and Location of Facilities--

Decanning facilities will probably be located on an industrial site which normally handles hazardous materials. Storage areas will be provided for both full and empty herbicide containers. Existing storage tanks would probably be used for storage of liquid to be incinerated. The facility would be selected to satisfy the following general criteria:

- It should not be located in populated areas. It could be located in an industrial area.
- It must provide adequate security. It should be fenced and have gates which provide controlled, limited access.

- It should not be in a fault area nor in a 100 year flood plain. (This is a requirement under RCRA regulations, 40 CFR 265).
- It should be located so as to minimize transportation time and distance to the ship loading dock and the at-sea incineration site.
- It should have an on-site, high efficiency chemical incinerator, preferably a rotary kiln incinerator.
- It should have an on-site storage capability for silvex stocks in containers and for decanned silvex.
- It should have an existing pipeline, rail line, or paved roads to the ship loading dock.
- It should have pumping equipment for use at the loading dock during ship loading.
- It should be in compliance with regulations promulgated under RCRA and all other pertinent Federal, state, and local regulations.
- It should be staffed by personnel equipped and trained in handling hazardous materials.

Incineration of the liquid silvex herbicide will take place within the confines of one of two designated ocean incineration sites: the Gulf Coast Ocean Incineration Site (GIS) or a site in the North Atlantic ocean presently under consideration (AIS). The size and location of the GIS and AIS are indicated in Figures 2 and 3.

2.2.1.3 Schedule--

Several administrative and logistical constraints govern scheduling of the herbicide disposal. Administrative constraints include letting of the decanning contract, assessing environmental impact, and issuing an at-sea incineration permit. Logistical constraints center on availability of an incinerator ship. The current best estimate places the earliest dates for at-sea incineration in the spring of 1981. Figure 4 shows the project schedule in bar chart form. Figure 5 shows the project schedule in a critical path form.

2.2.1.4 Cost--

The major cost components of the proposed action are decanning, at-sea incineration, and environmental monitoring. Separate contractors will be responsible for each task. Estimated total cost (March 1980) for this

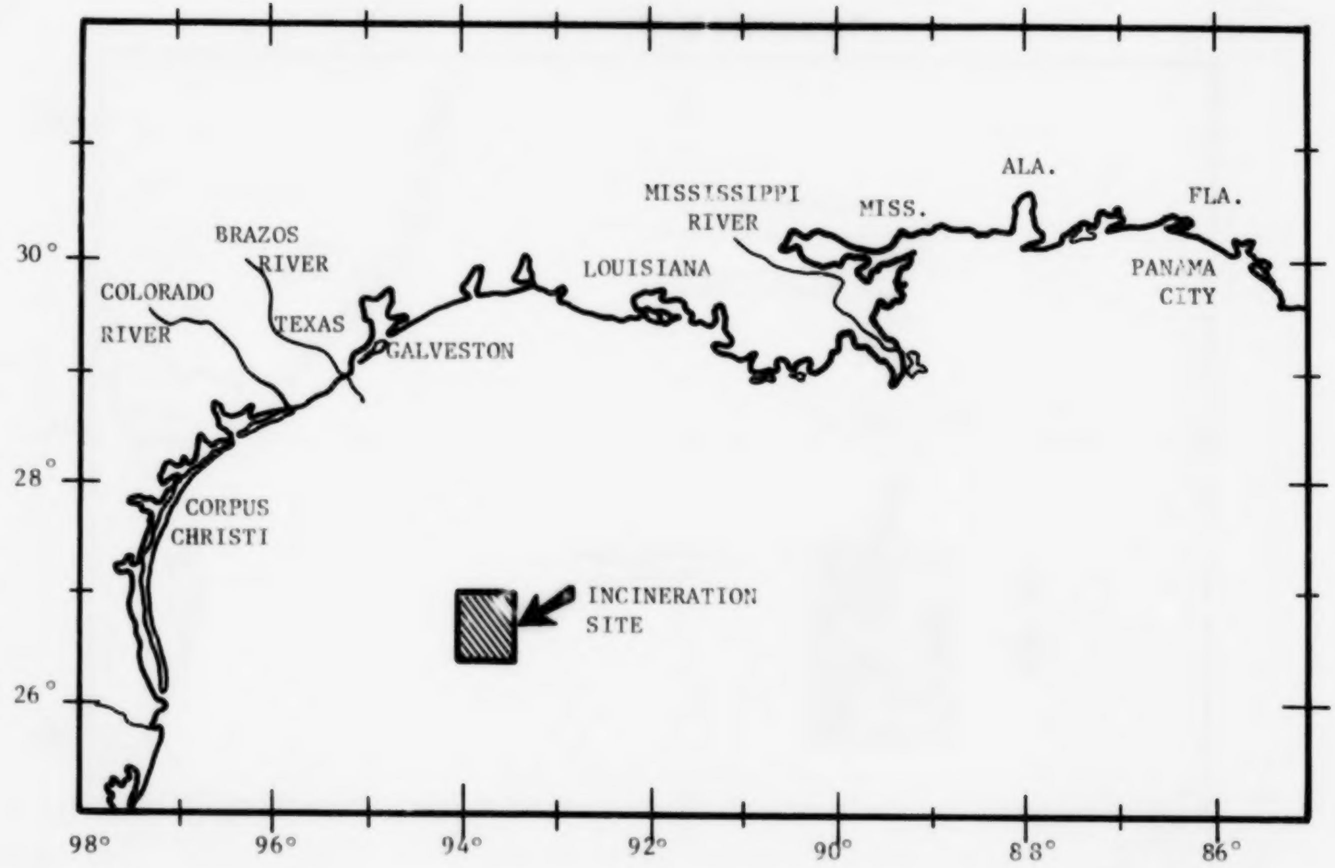

MISSISSIPPI
RIVER
MISS.
ALA.
FLA.
BRAZOS
RIVER
COLORADO
RIVER
TEXAS
GALVESTON
LOUISIANA
PANAMA
CITY
CORPUS
CHRISTI
INCINERATION
SITE
30°
28°
26°
98°
96°
94°
92°
90°
88°
86°

Figure 2. Geographical relationship of Gulf Ocean Incineration Site to nearby land masses (4).

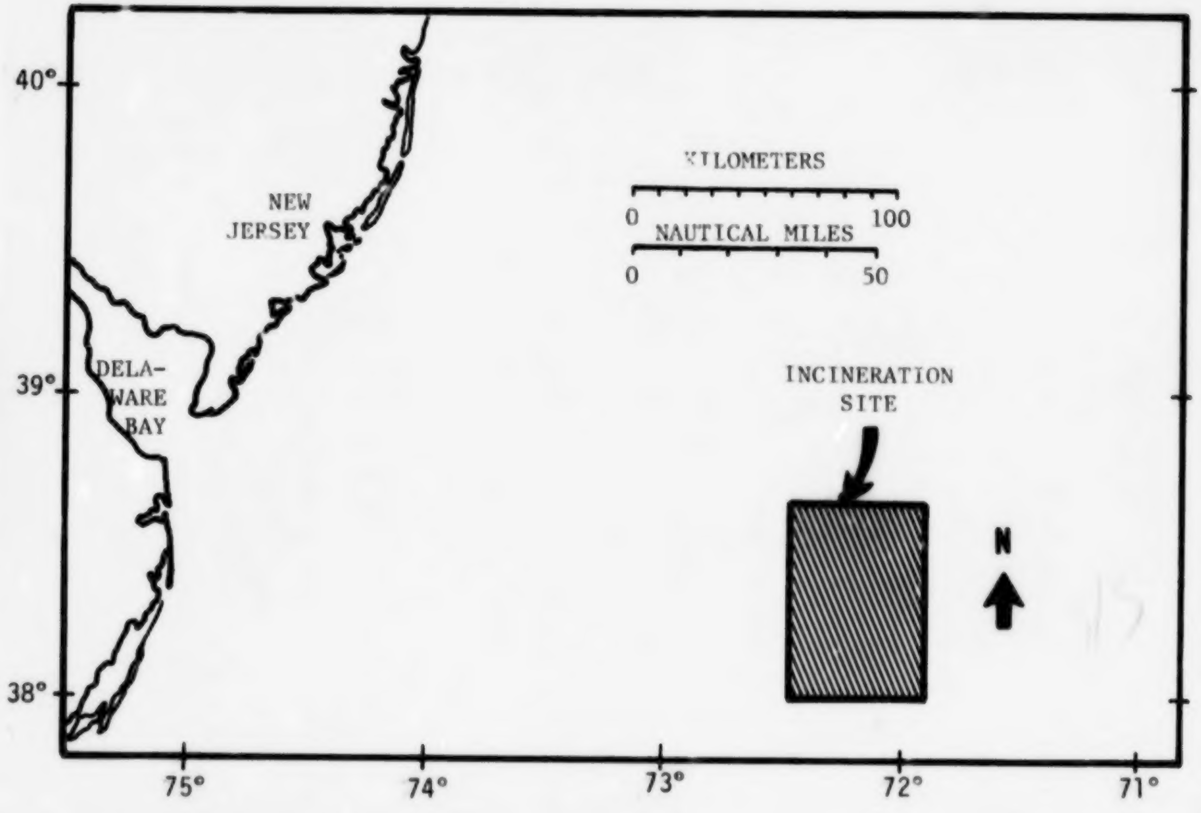

40°
39°
38°
75°
74°
73°
72°
71°
NEW JERSEY
DELA-WARE BAY
KILOMETERS
0
100
NAUTICAL MILES
0
50
INCINERATION SITE
N

Figure 3. Geographical relationship of proposed Atlantic Ocean Incineration Site to nearby land masses (5).

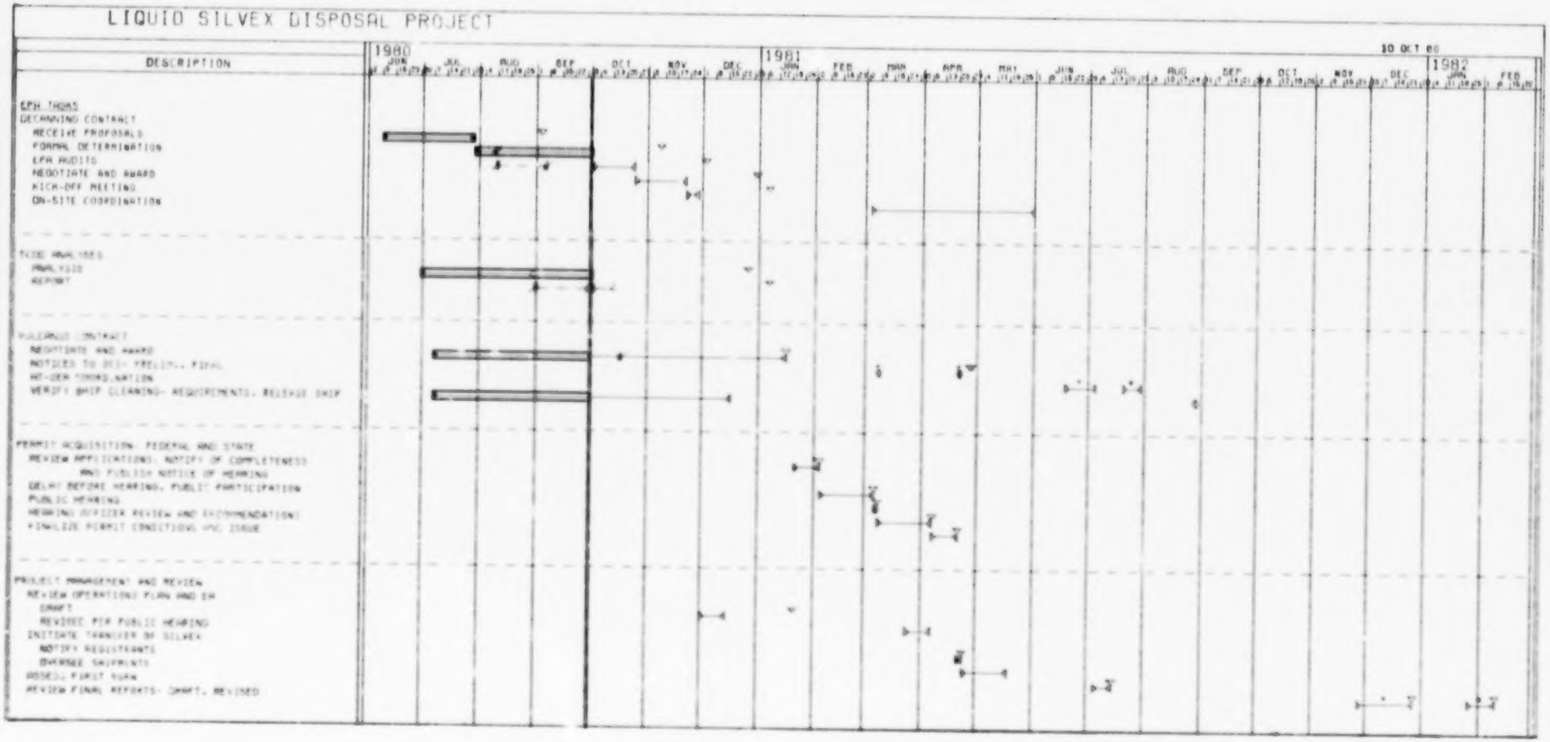


Figure 4. Proposed project schedule

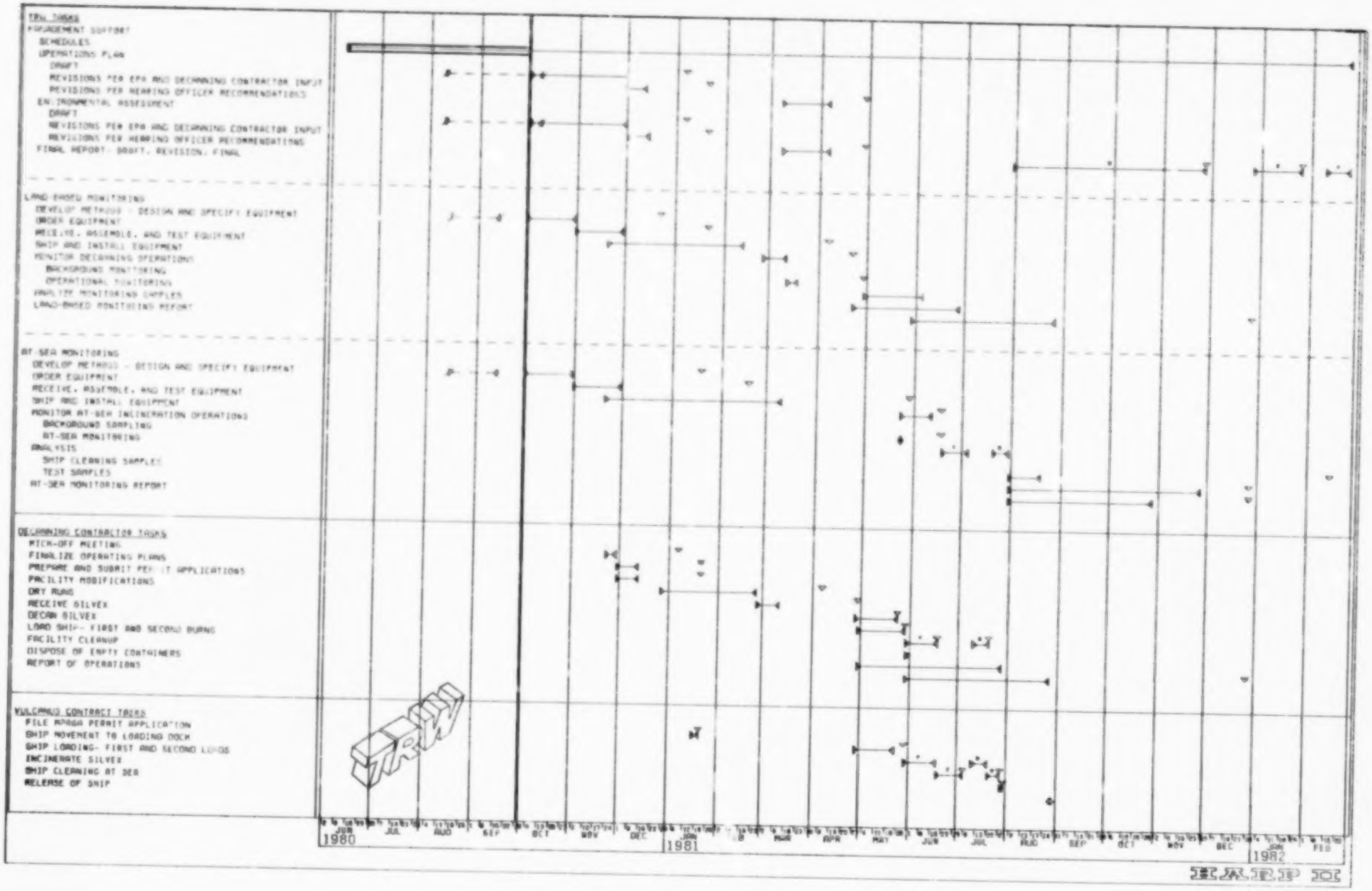


Figure 4. (Continued)

disposal alternative of incinerating 1.2 million gallons of liquid silvex by at-sea incineration ranges from 1.9 to 2.5 million dollars.

2.2.2 Environmental Impacts

In sections 2.2.2.1 through 2.2.2.3, the environmental impacts of normal at-sea incineration operations are described. The impacts of potential accidents and malfunctions are discussed in section 2.2.2.4. During normal operations, airborne release of combustion products containing HCl will constitute the major pollutant discharge to the biosphere. However, because of the remoteness of the incineration site, pollutants will not impact human populations. Moreover, impingement of the plume on the ocean and subsequent dissolution of HCl in seawater will not significantly impact the aquatic environment because of the already high buffering capacity and chloride content of seawater. The potential noise, socioeconomic, archaeological/historical, energy, and land use impacts of the silvex disposal action are negligible.

2.2.2.1 Air Quality--

2.2.2.1.1 Decanning, transport, and ship loading--The use of charcoal absorbers to filter air exhausted from the decanning facility or venting exhaust air into an operating incinerator would prevent air pollution from this phase of the at-sea incineration option. Limited biomonitoring will be undertaken to ensure the efficacy of this approach (3).

Transportation of herbicide from the decanning facility to the loading site by pipeline, rail tank car, or tank truck would not entail release of vapors to the atmosphere under normal operation conditions.

Small amounts of herbicide vapor will be released from ship loading operations, since vents on the ship's waste tanks are connected to a common pipe and vented to the atmosphere through a port on the foremast. Such vapor emissions will be negligible, and control measures are deemed unnecessary.

2.2.2.1.2 Incineration operations--Combustion of silvex herbicides results in near-complete conversion of the carbon, hydrogen, and chlorine in the formation into CO_2, H_2O, and HCl. Small amounts of CO (from incomplete combustion) and SO_2 (from the small amount of sulfur in the herbicide) are also formed. A destruction efficiency of at least 99.9 percent will be achieved by incineration. Since herbicide destruction efficiency is not complete, some toxic organic emissions will result. Maximum estimated sea-surface concentrations of silvex, 2,4-D and TCDD based upon a 99.9 percent destruction efficiency are approximately 38 ng/m^3, 76 ng/m^3, and 0.011 pg/m^3, respectively. These concentrations are several orders of magnitude below maximum permissible levels for each of these compounds.

Plume dispersion modeling (Appendix E) has been used to simulate the air quality impacts of at-sea incineration. Results obtained using worst-case assumptions indicate maximum sea-level concentration of emitted pollutants will occur 15.5 km downwind of the incinerator ship. Thus, the air quality impacts will be confined to the incineration site. Even if long-range transport of emitted pollutants is considered, extreme dilution would occur and prevailing westerly winds would have to carry pollutants over 1000 km before land masses would be impacted.

2.2.2.2 Water Quality--

As with air quality impacts, changes in water quality will be transient, negligible, and highly localized. Water quality impacts will result primarily from impingement of HCl and traces of unburned herbicide from the plume onto the ocean. Changes in the pH of seawater from dissolution of HCl from the plume will be buffered by the sea's alkaline salts, and any change is expected to be temporary and less than 0.2 pH units. Increases in chloride ion concentration, assuming an extremely conservative 2-meter mixing depth, would be of the order of 0.1 percent, with actual increases probably one or two orders of magnitude lower. Tides and currents would further reduce the impact of chloride by dilution. Using the same 2-meter mixing depth, the concentrations of 2,4-D and 2,4,5-TP would be in the nanogram (10^{-9} grams) per liter range (parts per trillion), while the concentration of TCDD would be less than one femtogram (10^{-15} grams) per liter (parts per quintillion), well below levels known to cause effects.

2.2.2.3 Soil, Flora, and Fauna--

Impacts on soil, flora, and fauna as a result of at-sea incineration will be primarily confined to plankton within the burn zone. These small floating plants and animals will be exposed to HCl and unburned herbicide from the plume. However, based on plume modeling and toxicological data, the concentration of herbicide components will be orders of magnitude lower than the levels at which toxic effects have been observed. Overall effects on ocean biota will be localized and temporary. The speed with which dilution reduces the concentration of the toxic herbicide species in the ocean and the low density of marine biota in the burn zones further lessen the probability of any lasting adverse impacts.

2.2.2.4 Potential Accidents and Malfunctions--

The potential impact of a herbicide spill during decanning is reduced by design features of the facility which prevent escape of liquid and vapor to the environment. The danger of explosion caused by ignition of herbicide vapor will be reduced by strict adherence to fire codes for flammable materials. Potential impacts on public health and the environment are considered minimal.

The safest mode of transportation existing between the decanning facility and the ship loading dock will be used to prevent herbicide spills during transport. Crews will be prepared to contain a potential spill with absorbent materials placed along the transport route and at key pipe and hose couplings. The risk of an accident which would impact the general public will be minimized.

During ship loading, provisions will be made to prevent accidental leaks from flex line connections. Spills from shipboard tanks will be absorbed on deck and otherwise prevented from reaching the harbor. Possible contamination of bilge water could occur, due to tank or pump seal leaks; however, if any herbicide were released via this route, it would be a very small amount. Only a catastrophic spill of the ship's cargo in the harbor would have a serious environmental impact, and the possibility of such an accident is remote.

Incinerator malfunction or changes in wind conditions could cause impingement of the plume on the ship, resulting in a hazard to the crew. However, based on past experience with at-sea incineration, such incidents are infrequent, of short duration (less than one minute), and leave little, if any, detectable herbicide residue. Automatic shutdown features of the incinerator would prevent release of unburned herbicide in the event of a flameout. Here again, only a catastrophic event requiring jettisoning of the cargo would represent a serious environmental impact. Even if this were to occur, the remote location of the ocean incineration site, the tremendous dilution offered by the open ocean, the properties of the herbicide (e.g., rapid hydrolysis to less toxic acids), and the already low productivity of the incineration site would all tend to mitigate the impacts of large scale release of the herbicide in the open ocean.

In general, the impacts of potential accidents and malfunctions can be minimized by proper contingency planning. Contingency plans will be drafted for all phases of the operation, once site-specific details are determined. These plans, described in more detail in Reference 3, will address the key elements of preparedness, prevention, notification, and emergency procedures.

2.3 LAND-BASED INCINERATION

The principal alternative to at-sea incineration for the disposal of liquid silvex formulations is land-based incineration. Key differences in the operations and environmental impacts of the land-based option vis-a-vis at-sea incineration are described in the following sections.

2.3.1 Description of the Proposed Action

Figure 5 is a schematic diagram of the land-based incineration alternative. The notable difference between land-based and at-sea incineration is that land-based incineration produces a liquid effluent stream containing a high level of total dissolved solids (from HCl and alkaline sorbents) and trace quantities of unburned herbicide. Disposal of this liquid effluent in an environmentally safe manner adds substantially to the cost of land incineration.

2.3.1.1 Operation and Maintenance Requirements--

2.3.1.1.1 Decanning--Decanning operations for land-based incineration are identical to those for at-sea incineration, described in section 2.2.1.1.

2.3.1.1.2 Transport of herbicide to incinerator--The amount of herbicide transport required and the consequent environmental risk for land-based

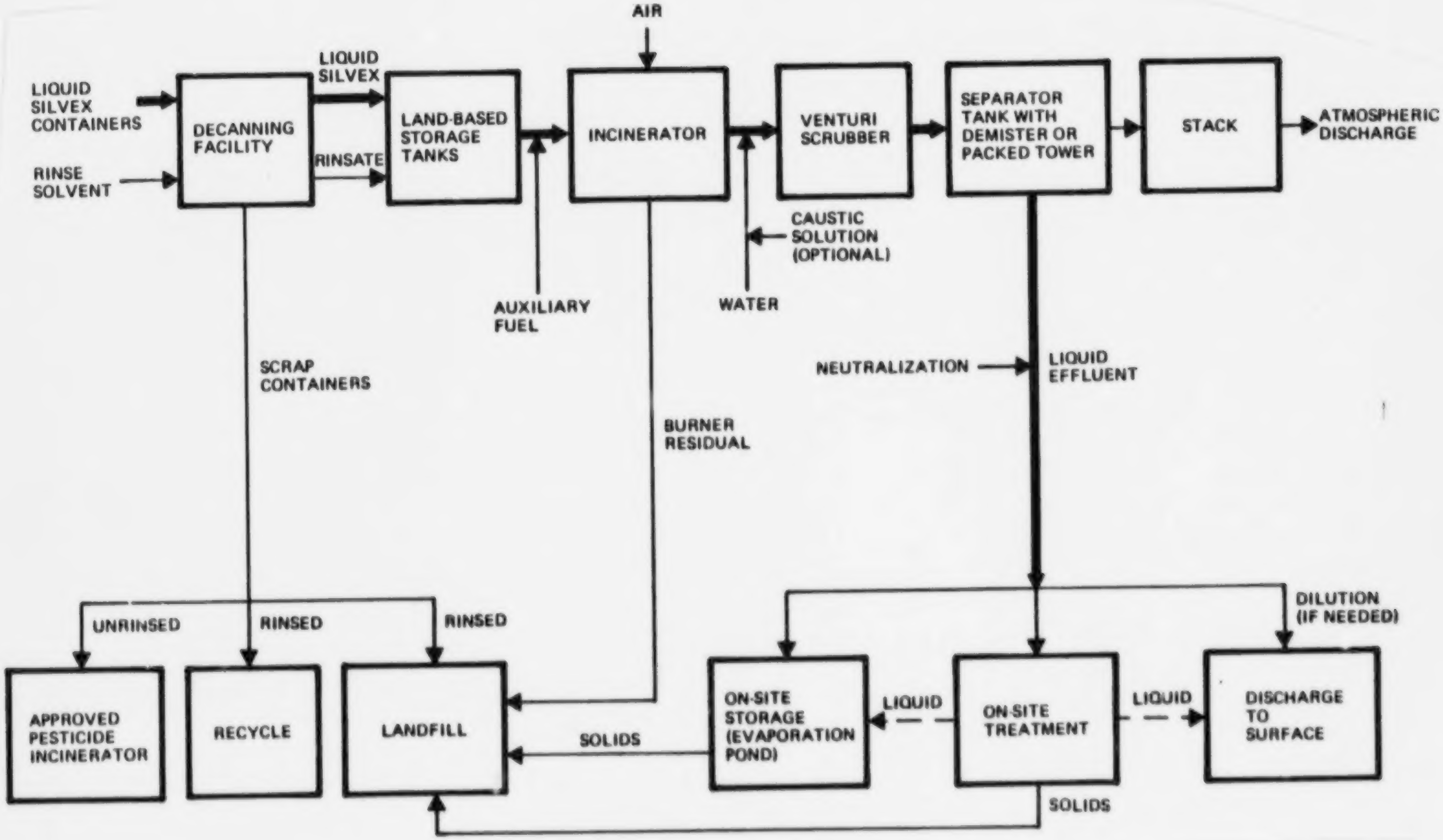

AIR
LIQUID SILVEX CONTAINERS
RINSE SOLVENT
DECANNING FACILITY
LIQUID SILVEX
RINSATE
LAND-BASED STORAGE TANKS
AUXILIARY FUEL
INCINERATOR
WATER
CAUSTIC SOLUTION (OPTIONAL)
VENTURI SCRUBBER
SEPARATOR TANK WITH DEMISTER OR PACKED TOWER
STACK
ATMOSPHERIC DISCHARGE
SCRAP CONTAINERS
BURNER RESIDUAL
NEUTRALIZATION
LIQUID EFFLUENT
UNRINSED
RINSED
RINSED
DILUTION (IF NEEDED)
APPROVED PESTICIDE INCINERATOR
RECYCLE
LANDFILL
SOLIDS
ON-SITE STORAGE (EVAPORATION POND)
LIQUID
ON-SITE TREATMENT
LIQUID
DISCHARGE TO SURFACE
SOLIDS

Figure 5. Schematic diagram of land-based incineration operations.

incineration is less than for at-sea incineration. Decanned herbicide can be transferred to tanks from which a land-based incinerator can be fed directly, without intermediate transfer to an incinerator ship. Site-specific details are, as yet, undefined.

2.3.1.1.3 Incineration operations--Incineration procedures are essentially identical for land-based and at-sea incineration except for rigorous treatment of effluent gases. Additional process equipment and environmental sampling/analysis are required to treat gaseous and liquid effluents and to monitor pollutant discharges. Land-based incineration is now regulated by RCRA (40 CFR 265).

2.3.1.1.4 Waste disposal--Gaseous emissions of chlorinated species (mainly HCl, but including trace amounts of unburned herbicide) will be controlled by a wet scrubber. While this method reduces air emissions, it creates a liquid waste disposal problem. Three methods of disposal for scrubber effluent are possible, all regulated by RCRA (40 CFR 265):

- Total containment by impoundment with disposal of liquid by evaporation and settled solids by landfill is the most economical option. However, it would be feasible only in regions of net evaporation (evaporation rate exceeds precipitation rate) since in a net precipitation region pond level would continue to rise, and the impoundment would be a permanent source of environmental concern.
- Discharge of scrubber water to surface waters, with or without dilution, is possible. An NPDES permit would be required. Monitoring costs and environmental impacts are potentially high for this option.
- On-site treatment of liquid effluent would entail liquid-solid separation followed by disposal of solids by landfilling and liquids by evaporation or treatment and discharge. Liquid-solid separation could be accomplished by mechanical means or in settling ponds. Treatment of liquids to remove contaminants prior to discharge would require additional cost for equipment.

2.3.1.2 Size and Location of Facilities--

The need for disposal of liquid effluents from land-based incineration necessitates a much larger facility than would be required for the land-based activities of at-sea incineration. Site selection must take into account the area required for surface impoundments and/or treatment facilities for waste scrubber slurry.

Any land-based incineration facility will be located nearer populated areas than either proposed ocean incineration site. As such, the impacts of normal operations and accidents/malfunctions on the human population would be potentially more severe than if the silvex herbicides are incinerated at sea.

2.3.1.3 Schedule--

Scheduling of a land-based incineration program for disposal of liquid silvex herbicides would be subject to potentially longer delays prior to start-up than an at-sea incineration program. Such delays could be precipitated if suitable on-site facilities for disposal of scrubber slurry were not already in existence. While virtually all commercial land-based hazardous waste incineration facilities are equipped with scrubber systems, the extent to which these systems comply with RCRA is not known. Because the proposed action must be performed in compliance with RCRA, many months could be required before incineration could begin if compliant impoundments and/or treatment facilities had to be constructed.

A model land-based chemical waste incinerator has a maximum waste feed rate of 750 gallons per hour which is larger than that of most existing land-based facilities. To incinerate the estimated 1.2 million gallons of liquid silvex and 120,000 gallons to container rinsate would require more than 70 days of continuous, 24-hour operation, nearly 3 times longer than at-sea incineration.

2.3.1.4 Cost--

The cost of land-based incineration would likely exceed the cost of at-sea incineration, but it is difficult to estimate. The additional cost of land-based incineration is almost exclusively caused by the additional expenditures for pollution control required for safe disposal of waste products from combustion. Estimated cost of the land-based incineration alternative ranges from 2.6 to 3.2 million dollars.

2.3.2 Environmental Impacts

In Sections 2.3.2.1 through 2.3.2.3, the environmental impacts of normal land-based incineration operations are described. The impacts of potential accidents and malfunctions are discussed in section 2.3.2.4. During normal operations, proper disposal of wastewater from operation of the stack gas scrubber will be the major environmental concern. The method chosen for disposal of this liquid effluent will determine what impacts land-based incineration will have on the environment. The potential for noise, socioeconomic, archaeological/historical, energy, and land use impacts of land-based incineration is expected to be minimal.

2.3.2.1 Air Quality--

2.3.2.1.1 Decanning and transport--Since the procedures for decanning and transport will be essentially the same as for the at-sea incineration alternative, the environmental impacts on air quality will be similar and are expected to be minimal for the land-based incineration alternative.

2.3.2.1.2 Incineration--Wet scrubbing of incinerator stack gases will reduce air emissions of HCl, particulates, and chlorinated organics from the facility. At least 99 percent HCl removal will be achieved by scrubbing, and total particulate emissions will be controlled to less than 180 milligrams per standard cubic meter (corrected to 12 percent CO_2), as required by RCRA regulations (40 CFR 265). Although emission controls will reduce airborne emissions from land-based incineration, some of the chlorine (less than one percent) present in the herbicide will be emitted as HCl. Plume dispersion modeling indicates that a maximum downwind HCl concentration of 0.6 $\mu g/m^3$ will occur about 1 km from the incinerator. This concentration is much less than the 7 mg/m^3 threshold limit value considered to be safe for 8-hour occupational exposure.

2.3.2.2 Water Quality--

Disposal of scrubber wastewater represents the greatest potential impact on water quality and the foremost environmental concern for normal land-based incineration operations. High loadings of solids, inorganic chlorides, and possibly organic compounds make direct discharge of the scrubber wastewater undesirable. Dilution does not decrease the total pollutant discharge. Therefore, treatment of some kind is necessary. Treatment normally includes clarification (to remove settleable solids) and neutralization. Resultant wastes are a neutralized wastewater, still containing a relatively high level of chlorides and dissolved solids, and a sludge consisting of solids from neutralization and particulate from combustion. In the past, neutralized wastewater from incineration of organochlorine wastes has been diluted and discharged either to sewer systems or surface waters. This discharge has an adverse effect on water quality. Should unburned herbicide be present in this wastewater, a relatively greater adverse impact would be realized. Disposal methods for impounded scrubber sludge must take into account that leachate containing metals or other pollutants can escape containment and enter the groundwater system. The treatment method chosen for scrubber wastewater will determine water quality impacts for land-based incineration. Hazardous waste regulations under RCRA (40 CFR 265) would probably put constraints on wastewater treatment options, and thus indirectly define what the water quality impacts would be.

2.3.2.3 Soil, Flora, and Fauna--

Soil, flora, and fauna downwind of the incinerator may be affected by air emissions from the facility. Slight acidification of soil from HCl emissions would be possible but would probably be insignificant because of emission controls. Effects on flora and fauna would be similarly minimal. Biota would more likely be affected by a wastewater discharge. Adverse effects on soil could occur via seepage from an unlined surface impoundment. As is the case for water quality impacts, the impacts on soil, flora, and fauna will be determined directly by the wastewater treatment method chosen and indirectly by applicable pollution control regulations.

2.3.2.4 Potential Accidents and Malfunctions--

In general, the impacts of potential accidents and malfunctions during land-based incineration would be greater than for at-sea incineration because of the proximity of land-based operations to population centers. More process operations are entailed in land-based incineration (including stack gas scrubbing and wastewater treatment), thus a greater potential for equipment malfunctions exists. Incinerator control system or treatment system malfunctions comprise the most likely events which could result in adverse environmental impacts. Accidents, including catastrophic spills or vandalism, could cause a greater adverse environmental impact, but are less likely to occur than equipment malfunctions. Proper countermeasures and contingency planning can minimize the risks inherent in handling and storage of silvex herbicides.

2.4 RETURN TO MANUFACTURERS FOR REPROCESSING

Section 6 (c) of FIFRA, under which the Administrator of EPA suspended and accepted the cancellations of the registrations of the liquid silvex herbicide formulations for home and garden use, does not mandate return to manufacturers. Under Section 19 (a) of FIFRA, EPA is committed to accept the cancelled herbicides at convenient locations for safe disposal as requested by the owners of the materials.

EPA and the Registrants have determined that it is neither technologically nor economically feasible to recover, recycle, or reprocess the liquid silvex. Three reprocessing methods were considered: photolysis, chlorinolysis, and fractionation. Reprocessing the herbicide into useable products would require major research efforts and capital expenditures. To dispose of the liquid silvex by returning it to the manufacturers for reprocessing would simply disperse the problem of research efforts and capital expenditures and would be inconsistent with Section 19 of FIFRA.

2.4.1 Photolysis

The principle of photolysis involves the dechlorination of the herbicide and TCDD compounds by ultraviolet radiation in the presence of an organic solvent that can donate hydrogen to the process. Laboratory studies (20) on TCDD have indicated the process to be stepwise. That is, the tetrachlorinated compound is first converted to the tri- then bi- and mono-chlorinated compounds. The less toxic mono-chlorinated compounds tended to be stable and did not further dechlorinate. In this manner the photolysis can reduce the toxicity of the silvex formulations but cannot completely alleviate the need to employ a permanent disposal method.

Since these laboratory-scale results are the only applicable experiments conducted to date, implementation of the photolysis option would require study of the pertinent engineering parameters, design, and construction of a facility to process the volume of silvex formulations to be disposed of, and incorporation of a final disposal scheme for the photolyzed material. Because of the uncertainties, time, and cost involved in developing a useful photolysis process, this approach was not selected even though it would appear at first view to be environmentally acceptable and to produce a useful and valuable product.

2.4.2 Chlorinolysis

From the theoretical engineering point of view, chlorinolysis offers an efficient, controlled, and safe method for disposal of the herbicide, as well as other hydrocarbon formulations. Chlorinolysis is a process that breaks down the molecule and adds chlorine atoms to produce carbon tetrachloride, phosgene, and anhydrous hydrogen chloride, all of which have established commercial value. This process would most probably follow fractionation of the silvex formulation to recover the kerosene (see section 2.4.3).

The U.S. Air Force (USAF) and EPA conducted a research project of chlorinolysis as a means to dispose of Herbicide Orange. No dioxin was detected at a sensitivity level of 10 ppt in the carbon tetrachloride product of one test run (8). A similar set of chlorinated by-products can be expected from the chlorination of silvex. However, use of the chlorinolysis method for the quantity of liquid silvex to be disposed of would amount to the development of a new engineering technology. As was discovered by the USAF in their disposal of 2.3 million gallons of Herbicide Orange, no commercial facility exists for this scale of operation. Cost estimates for designing and building such a facility for Herbicide Orange (including credit for the sale of chemicals produced) ranged from 4 to 11 million dollars (8). Such an undertaking was expected to require 3 to 5 years to complete.

Owing to the uncertainties and costs associated with developing this technique to a full scale plant, partial or total chlorinolysis was not selected as the method of disposal of Herbicide Orange, even though it was thought to be environmentally acceptable. Disposal of silvex by chlorinolysis would have to be preceded by the same kind of laboratory and pilot plant studies which were undertaken for Herbicide Orange.

2.4.3 Fractionation

Fractionation of the silvex formulations would involve separating the formulation components on the basis of a physical or chemical characteristic (for example, volatility or boiling point). Separation of the silvex formulations into the kerosene fraction and the herbicide fraction offers the very attractive benefits of recovering the kerosene and reducing the volume of herbicide to be disposed of.

Fractionation might be achieved by distillation or by passing the silvex formulations through activated carbon filters. A small scale study of distillation of Herbicide Orange was conducted, and it found distillation unacceptable (8). The reasons cited were the fact that the fate of dioxin could not be demonstrated, 3 percent of the Herbicide Orange processed could not be accounted for, and standards to control and monitor vapor and fluid emissions to the environment had not been identified. Further studies would have to be carried out to determine the acceptability of distillation for silvex. The use of activated carbon is similarly uncertain. Implementation of this option would require a pilot study to determine removal efficiencies, the fate of silvex, the fate of TCDD, and methods for the monitoring of fugitive emissions.

Either fractionation method would require a further disposal step for the resulting liquid or solid (i.e., absorbed on charcoal) product. Disposal methods discussed in this section (i.e., incineration, photolysis, chlorinolysis, and landfilling) for the silvex formulations apply equally well to the more concentrated products that would be obtained from fractionation.

The U.S. Air Force studied (21) processing herbicide Orange through activated charcoal. The method adequately reduced the TCDD content, but it was concluded that there was no satisfactory technology for disposing of the large number of stainless steel cannisters filled with TCDD-contaminated charcoal that would have been generated by a full scale fractionation reprocessing. Such technology has not been demonstrated in the four years since the U.S. Air Force study. The three stainless steel cannisters filled with TCDD-contaminated charcoal from the study are stored on Johnston Island because no suitable landfill could be located in the continental U.S.

2.5 SECURE LANDFILLS

Landfills suitable for the secure disposal of hazardous wastes operate primarily on the principle of isolation of wastes from man and the environment. Some detoxification of wastes can also occur with time through biodegradation and chemical degradation.

Regulations promulgated pursuant to RCRA govern secure landfills (40 CFR 265) and provide a minimum level of environmental protection which all facilities must meet. Beyond that level of protection, there is still a small probability of silvex escaping to the environment. The probability and consequences of escape will vary from site to site. Silvex can be placed in landfills while in the original containers, thus eliminating the environmental impacts and risks associated with the process of emptying the containers.

Disposal in secure landfills offers the option of a centralized or decentralized operation. The centralized option considered (8) involves disposing of all liquid silvex in the "Wes-Con" Missile Silos, which are located in a remote part of Idaho. These abandoned, underground missile silos have thick concrete walls and floors which would isolate the waste silvex from the environment. The U.S. Air Force considered and rejected this alternative for the disposal of Herbicide Orange (8).

The "Wes-Con" facility might be available for disposal of silvex at a cost of about 6 cents/lb. The total cost for disposal of liquid silvex would thus be about $432,000. A disadvantage of this site is the fact that access is very limited. Wastes would have to be transported by rail to the nearest depot and then trucked to the disposal site. The facility is located far from the majority of the Registrants, which could lead to major transportation costs and logistical problems for Registrants and the facility operator.

The option to dispose of silvex in a number of decentralized, secure landfills offers flexibility in choosing sites more conveniently located for shipping purposes. RCRA regulations would probably require sealing of the small individual containers in large (e.g., 55 gal.) metal drums. The drums will probably have to be buried along with an absorbent material to contain any leaks. Finding secure-landfill operators willing to accept liquid silvex may be a problem.

Disposal of liquid silvex in bulk volume would require 22,000 55-gallon drums at an approximate cost of $10 each. However, most of the liquid silvex is packaged in cans and bottles averaging one quart in size. If overpacking is required and absorbent material added, it is estimated that 44,000 drums would be needed at a cost of $440,000. Disposal of the drums is estimated to cost between $60 to $100 per drum. Therefore, total cost of this disposal alternative is estimated to range from $3,080,000 to $4,840,000. Landfilling may only postpone the problem for future generations when the drums eventually corrode, exposing the inner metal containers to corrosion and release of the silvex into the landfill site and, potentially, into the surrounding environment.

2.6 SLUDGE BURIAL

This disposal method can be viewed as a variation of the landfilling method, the difference being the enhancement of the biodegradation process in sludge burial. This option would involve the construction of trenches in geologically suited formations on government land. The type of formations picked for the trenches would preclude vertical and lateral movement of the silvex. The trenches would be filled with containers of silvex and would then be surrounded by secondary sewage plant sludge, which would provide a growth medium for the bacteria. The containers would be drilled with holes to allow a controlled release of silvex. The trenches would then be mounted with dirt fill and aggregate. Depending on the type of bacteria selected to decompose the silvex, vents might also be required.

Sludge burial was considered for the destruction of Herbicide Orange. However, there was a lack of interested and qualified industries to undertake the preliminary investigations (8). A similar problem would be likely to arise in the destruction of silvex by this method. Another serious drawback to this disposal method is the time period necessary to completely destroy the silvex, possibly as long as 10 to 25 years. The time required to develop a strain of bacteria suitable for the degradation of silvex is uncertain. During this period a monitoring system would have to be operated, and an earth covering would have to be maintained.

2.7 MICROBIAL REDUCTION

This process involves the biological degradation of the herbicide through fermentation. It requires the development of a microorganism to "feed" on the herbicide. From the literature, it appears that microorganisms have been developed which have excellent capabilities for handling organic compounds. However, two factors severely complicate the biological degradation of herbicides: 1) their insolubility in water, and 2) their chemical structure (specifically the number and position of chlorine atoms attached to the aromatic ring).

Very little work has been done on the microbial degradation of TCDD; however, Matsumura and Benezet (22) have studied the problem. Using 100 microbial strains, they found that only five strains showed some ability to degrade the compound. Thus far, Matsumura and Benezet have not been able to manipulate cultural conditions to increase the rate of degradation of TCDD in any of the microorganisms. Worne (23) reported in a paper presented at Ghent, Belgium, that he has developed mutated organisms which have the capability to cause 100 percent disruption of the aromatic ring of several chlorinated phenols. He reported a detention time of 52 hours for concentrations of 200 ppm.

Detoxification of the herbicide could be accomplished using one of many conventional systems, including lined stabilization ponds, activated sludge, anaerobic digestion, or complete mixing with activated sludge. Implementation of this method would require a pilot study to determine removal efficiencies, the fate of silvex, the fate of TCDD, and engineering parameters for the design and construction of microbial reduction facility. There presently are no facilities available to carry out this disposal method with the silvex formulations.

2.8 CONCLUSIONS

Two silvex disposal actions have been considered in detail: incineration at sea and land-based incineration. Incineration at sea is the preferred disposal alternative because it provides a lower potential for environmental impact and a shorter duration for the disposal action at a lower overall cost. Land-based incineration requires wet scrubbing to reduce the gas emissions and, therefore, generates a liquid scrubber waste stream requiring disposal. Also, because of the proximity of virtually all existing land-based hazardous waste incineration facilities to populated areas as compared to at-sea incineration sites, impacts of normal operation and accidents/

malfunctions on the human population would be potentially more severe during land-based incineration. The duration of at-sea incineration is estimated to be one third, or less, of that for land-based incineration; and the cost is approximately one half of that for land-based incineration. Hence, at-sea incineration is the preferred disposal action, although land-based incineration is the principal alternative.

Other alternatives examined included no action, returning the herbicide to the manufacturers for reprocessing, disposal in secure landfills, sludge burial and microbial reduction. Most of these alternatives are associated with potential long-term environmental impacts resulting from the extended storage of herbicide or herbicide contaminated materials, and are either too costly or have uncertain economics. Reprocessing alternatives such as photolysis, chlorinolysis, and fractionation would require extensive process development for commercial scale operation. Similarly, sludge burial and microbial reduction would require substantial developmental work prior to application of these technologies to the disposal of liquid silvex. These alternatives are therefore considered to be unacceptable for the safe, economical and timely disposal of liquid silvex formulations.

3. AFFECTED ENVIRONMENT

Chapter 3 describes the regional and local environments affected by the proposed action and the principal alternative. Descriptions of meteorological, hydrological, geographical, and biological conditions are provided so that environmental impacts can be assessed and discussed. Other activities in the vicinity of the site are also described. In most cases, detailed descriptions cannot be provided until final site selection is accomplished. In general, the marine environment would be most affected by at-sea incineration, while the land and navigable inland waterways would be most affected by land-based incineration.

Based on the locations of the Gulf Coast and proposed North Atlantic incineration sites, two regions have been selected for assessment of regional environmental impacts of the proposed projects' land-based operations. These regional areas are the Gulf Coast, generally extending from mid-Texas to the Florida panhandle, and the North Atlantic Coast, generally extending from mid-Virginia to Connecticut. Sections 3.1 and 3.2 describe synoptically the affected environments of these two regions, respectively. Sections 3.3 and 3.4, respectively, describe the local environments potentially affected by the proposed and alternative actions.

3.1 THE GULF COAST REGION

The Gulf Coast region is moderately populated and industrialized, compared to the North Atlantic region, but has areas of heavy population and industry, particularly around Houston, Texas, and New Orleans, Louisiana.

The Gulf Coast region is influenced primarily by a prevailing flow of warm tropical air from the Gulf of Mexico. Originating from the westward extension of the Azores High, this maritime air provides adequate rainfall and a humid subtropical climate across much of the region. Southerly winds are predominant over the entire region. Similar conditions prevail from Corpus Christi to the Florida panhandle. The coastal areas are also influenced by the diurnal sea breeze, which penetrates approximately 25 miles inland.

In order to provide a synoptic overview of the Gulf Coast region, key meteorological data for a number of surrounding locales have been presented in Table 1 (24). These data provide an indication of the consistency of climate over this general area.

The information discussed in Table 1 includes prevailing wind speed and direction, days of thunderstorm activity, days of poor visibility, precipitation, and heating and cooling degree days. The values in Table 1 are summations over an annual period. The heating degree day is a measure based on the number of degrees the daily mean temperature is below 65°F. Cooling degree days are determined in an analogous manner. These numbers are excellent indicators of long term temperature differences between two areas. A high value for heating degree days indicates a high occurrence of uncomfortably cold weather. A high value for cooling degree days indicates a high occurrence of uncomfortably hot weather.

Table 1 shows that air flow over this entire region is reasonably constant, as evidenced by comparable wind speeds and directions. The coastal cities all show precipitation over 100 cm/year. In general, these same cities also have a high incidence of low visibility. The heating and cooling degree day information indicates that there is a continuum of temperature change in this region, with temperatures decreasing from south to north and from west to east. Thus, it can be concluded that air circulation is regional in nature, but that the coastal and inland areas are distinct in terms of precipitation and other moisture related phenomena.

Calculation of mean mixing heights on an annual basis indicates that mixing heights of 500 meters are typical in the morning and may rise to 1200 meters in the afternoon (25). As yearly means, these values are appropriate to the general Gulf Coast region but give no detailed account of the seriousness of specific air pollution incidents involving low mixing heights. However, seasonal means show that these heights are somewhat lower (400 meters in the morning) for the fall and winter months.

Incidences of adverse weather conditions have been tabulated and presented on a regional basis (26). Freezing precipitation, such as sleet, is rare throughout the region and large hail (stones greater than 16 mm) occurs

TABLE 1. MEAN ANNUAL METEOROLOGICAL DATA FOR COMMUNITIES IN THE GULF COAST REGION (1941-1970)

Location	Prevailing Wind		Days of Thunderstorm Activity	Days of Visibility Less Than 1/4 Mile	Normal Precipitation (Water Equivalent) cm	Heating Degree Days	Cooling Degree Days
	Speed, m/sec	Direction					
Corpus Christi, TX	5.36	SSE	31	29	72.5	930	3474
Galveston, TX	4.92	---	--	--	107.2	1235	3004
Houston, TX	3.31	SSE	72	39	122.4	1396	2889
Port Arthur, TX	4.56	S	64	41	139.9	1447	2798
Lake Charles, LA	3.93	S	76	48	140.9	1459	2739
New Orleans, LA	3.75	---	68	31	144.2	1465	2706
Mobile, AL	4.16	N	80	39	170.1	1684	2577
Pensacola, FL	3.71	---	72	37	163.1	1578	2695

occasionally. The region lies in the cyclone belt, and approximately 10-15 percent of its precipitation during the cyclone season (June through October) is attributable to these storms. Tornadoes also occur at a rate of 4 to 8 per 26,000 square kilometers per year. The number of tornado occurrences is greater near the coast than inland.

As might be expected, the geological factors which could affect this project's environmental impacts vary within the region. However, there are locales within the region where the geological conditions would minimize potential impacts of the land-based operations. Specifically, there are locales with impervious, clayey soils and deep aquifers.

Runoff in some of these locales is relatively slow. During infrequent periods of intense general rainfall, large volumes of water are stored in the valleys of the basins and are then slowly released to the streams. Thus, floods tend to be slow moving and have broad flat-crested peaks.

3.2 THE NORTH ATLANTIC REGION

The North Atlantic region, extending from mid-Virginia to Connecticut, is more heavily populated and industrialized than the Gulf Coast region. In particular, the area from Washington, D.C., to Boston is very densely populated; and the area from Philadelphia to Connecticut has heavy industrial concentrations.

The North Atlantic region is influenced primarily by transcontinental air moving from west to east across North America. Much of the region is subject to storms of Great Lakes origin. Regional climate is typified by long, sometimes uncomfortably hot summers and mild winters. The freeze-free season averages 170-200 days, and precipitation is typically 92-115 cm annually. Calms, which may last up to a week, occur during the late summer. A thin strip of coastal area is dominated by marine conditions, particularly by diurnal see breezes.

In order to provide a synoptic overview of the North Atlantic region, key meteorological data for a number of surrounding locales have been presented in Table 2 (24). These data provide an indication of the consistency of climate over the general area.

TABLE 2. MEAN ANNUAL METEOROLOGICAL DATA FOR COMMUNITIES IN THE NORTH ATLANTIC COAST REGION (1941-1970)

Location	Prevailing Wind		Days of Thunderstorm Activity	Days of Visibility Less Than 1/4 Mile	Normal Precipitation (Water Equivalent) cm	Heating Degree Days	Cooling Degree Days
	Speed, m/sec	Direction					
Norfolk, VA	4.74	SW	37	23	113.5	3488	1441
Washington, DC	3.40	---	26	37	101.9	5010	940
Baltimore, MD	4.25	W	28	30	102.8	4654	1108
Atlantic City, NJ	9.83	S	26	48	115.5	4812	869
Wilmington, Del.	4.07	NW	31	39	102.2	4930	992
Philadelphia, PA	4.29	WSW	26	26	101.4	5101	1104
Harrisburg, PA	3.44	WNW	33	20	92.6	5251	1025
Allentown, PA	4.25	W	32	29	107.9	5810	772
Trenton, NJ	4.02	S	33	--	102.0	4980	968
New York, NY	4.20	NW	19	--	102.1	4848	1068
Bridgeport, CN	5.36	SW	22	29	98.1	5461	735
Providence, RI	4.83	SW	21	26	108.6	5972	532
Nantucket, MA	5.90	SW	20	98	110.9	5891	--

The information presented in Table 2 includes prevailing wind speed and direction, days of thunderstorm activity, days of poor visibility, precipitation, and heating and cooling degree days. All of these are mean annual averages. The basis of the heating and cooling degree day measurements is discussed in section 3.1.

Reference to Table 2 shows that prevailing air flow is generally out of the west at every point. The northern and coastal areas show marked differences. No continuity can be seen in the wind speed averages, except that all of the points closest to Philadelphia have similar measurements. The region is also fairly homogeneous with regard to precipitation. Incidences of thunderstorm activity and rainfall are well distributed.

There are four common habitats in the North Atlantic Region including forests, successional areas (urban and rural), cultivated areas, and wetlands. The major types of central forest found in the region are: 1) Riparian Forest in the flood plains; 2) River Birch-Swamp Maple Forest along streams to higher elevations; 3) Deciduous Forest; and 4) White Oak Forest in higher elevations. Large areas of land were cleared in the past and now consist of successional habitats. Some of this land is cultivated to produce such products as hay, grain, fruits, and vegetables. Wetlands are likely to be near the areas where shiploading may occur. These are very diverse habitats.

3.3 INCINERATION AT SEA

The principal tasks of the preferred action as described in Chapter 2 are: decanning, transportation to the ship loading dock, ship loading, at-sea incineration operations, and ship cleaning. Detailed operational plans are given in Reference 3. Several of the tasks are exclusively land-based (i.e., decanning and transportation to the ship), ship loading occurs in part on land and in part on water, and incineration and ship cleaning take place at sea. For purposes of continuity, the environments affected by each of the principal tasks of the proposed action are described in the order given above.

3.3.1 Decanning Operations

3.3.1.1 Meteorological Conditions--

Specific meteorological conditions cannot be addressed since the locations of the decanning facility has not yet been defined. However, decanning will probably take place in close proximity to the ship-loading site. In the event that the designated Gulf of Mexico incineration site is employed, general meteorological data for the Houston area could be used (see section 3.3.4.1). No statement can be made about burning in the North Atlantic at this time. Local winds and precipitation will be the only factors of significance for environmental transport of any gases escaping from this operation.

3.3.1.2 Hydrological Conditions--

Pertinent hydrological information would include location and flow of nearby surface waters, depth of water table, type and permeability of subsoil, and probability of flooding. Specific data cannot be addressed prior to selection of the decanning facility.

3.3.1.3 Geological Conditions--

Pertinent geological information would include seismic risk zone category, and the type, depth, and chemical character of topsoil which may be affected by a herbicide spill. Specific data cannot be addressed prior to selection of the decanning facility.

3.3.1.4 Biological Conditions--

Pertinent biological information would include type and location of indigenous flora and fauna and the proximity and density of centers of human population. Specific data cannot be addressed prior to selection of the decanning facility.

3.3.1.5 Other Activities in the Vicinity of the Selected Facility--

Decanning operations will probably be carried out in a facility built especially for this purpose and located on an industrial site where hazardous materials are normally handled. Activities in the immediate vicinity of such a site would include loading and unloading operations, tank and drum storage, and chemical processing. The decanning facility will likely be far enough from residential areas so that noise or odors from the decanning facility will not impact the local population.

3.3.2 Transportation to the Loading Site

3.3.2.1 Meteorological Conditions--

Specific meteorological conditions cannot be addressed prior to selection of the decanning facility and the transportation route for the bulk movement of decanned liquid silvex. However, in the event of burning in the Gulf incineration site, it can be assumed that meteorology for the Houston area will be applicable (see section 3.3.4.1). No statement can be made regarding the North Atlantic at this time. Whatever the location, local winds and precipitation would be factors influencing environmental transport of any escaped vapors. Also, inclement weather or poor visibility may increase the probability of an accident.

3.3.2.2 Hydrological Conditions--

Information required would be the same as noted in section 3.3.1.2. Specific data cannot be addressed prior to selection of a transportation route.

3.3.2.3 Geological Conditions--

Information required would be the same as noted in section 3.3.1.3. Specific data cannot be addressed prior to selection of a transportation route.

3.3.2.4 Biological Conditions--

Information required would be the same as noted in section 3.3.1.4. Specific data cannot be addressed prior to selection of a transportation route.

3.3.2.5 Other Activities in the Vicinity of the Site--

If liquid silvex formulations are transported to the ship loading site via rail tank car or tank truck, vehicular activity may be affected. Traffic may be controlled on existing roads or rail lines while the herbicide is being transported.

3.3.3 Ship Loading Operations

3.3.3.1 Meteorological Conditions--

No specific site has been defined for the ship loading operation. If the proposed action takes place in the Gulf of Mexico, ship departure from Deer Park, Texas, may be the case. In this event, general meteorology for the Houston area would be applicable (see section 3.3.4.1). No statement can be made regarding the North Atlantic site at this time. Local winds and precipitation will have the greatest effect on distribution of any escaped vapors. Inclement or freezing conditions may increase the probability of an accident or mechanical failure. Also, with such close proximity to the ocean, some effects may be felt from diurnal sea breezes. These occur because of temperature differences between the sea and land surfaces, with wind blowing towards the open sea at night, and reversing direction during the day. These effects only occur within a few miles of the ocean, and are less prevalent during colder seasons.

3.3.3.2 Hydrological Conditions--

Tidal information may be pertinent although specific hydrological data cannot be addressed prior to selection of the ship loading site.

3.3.3.3 Geological Conditions--

Characteristics of bottom sediment in the harbor may be pertinent although specific geological data cannot be addressed prior to selection of the ship loading site.

3.3.3.4 Biological Conditions--

Pertinent biological information would be the same as noted in section 3.3.1.4. Specific data cannot be addressed prior to selection of the ship loading site.

3.3.3.5 Other Activities in the Vicinity of the Site--

Normal dockside activities will proceed concurrently with ship loading for both the incineration ship and other vessels in the harbor. This includes transportation of cargo and personnel to and from docked vessels, loading/unloading of vessels, and arrival/departure of vessels and tugs.

3.3.4 The Gulf Coast Incineration Site

Figure 2 shows the relationship between the Gulf Coast incineration site and nearby land masses. This site, designated by EPA (4) for at-sea incineration of organochlorine wastes, is located in the northern Gulf of Mexico and is centered 355 km ENE of the Texas-Mexico border, 315 km SSE of Galveston, Texas, and 350 km S of Cameron, LA. At its nearest point to land, the site is 210 km S of Sabine Pass, Texas. It is a parallelogram with corners at:

- 27° 16' 12" N - 93° 24' 15" W
- 26° 32' 24" N - 93° 15' 30" W
- 26° 12' 00" N - 93° 56' 00" W
- 26° 32' 40" N - 94° 04' 40" W

This is essentially the same site in which organochlorine wastes were incinerated in late 1974 (16) and early 1977 (15), although the site has been reoriented to coincide with the LORAN-C time delay line grid. This reorientation eliminates previously required navigational calculations and gives greater assurance that incineration ships will remain within the designated boundaries. Subsequent sections describe the meteorological, hydrological, geological, and biological conditions in the Gulf Coast incineration site.

3.3.4.1 Meteorological Conditions in the Gulf Coast Incineration Site--

Meteorology of the Gulf Coast incineration site has been well documented in the Environmental Impact Statement designating this site (4). This document assimilates data provided by the National Climatic Center, the U.S. Navy Hydrographic Office, and other sources. It is assumed to be the best summary of available information for the site. Meteorological phenomena of interest to this study include winds, storms, precipitation, visibility, relative humidity, ambient air temperature, and atmospheric stability.

3.3.4.1.1 Winds--Data on these parameters are incorporated by reference to the Gulf Coast EIS (4). Prevailing winds are generally from the east, although strong northerly components are also evident near the beginning and end of the year. Mean wind speeds follow a similar annual cycle. Maxima can be found in the early and late months, with a minimum at midyear. Mean wind speeds range from 7 to 10 knots (3.5-5 m/sec) between June and September and 15-18 knots (7.5-9 m/sec) between November and January, with a mean wind speed of only 11 knots (5.5 m/sec). A more detailed breakdown is presented in Reference 4.

Unusual winds, known as Northers, may occur between the months of November and April. A Norther is a cold, abnormally high speed wind from the North, lasting from 3 to 4 days. They are usually preceded by warm, rainy conditions from the South. Substantial Northers can be expected up to 6 times in any given year.

3.3.4.1.2 Precipitation and storms--Although precipitation may be considerable in the Gulf of Mexico region, no data could be found for the open ocean. Precipitation in the coastal areas amounts to 70 cm/yr at Corpus Christi, and 105 cm/yr at Galveston, almost entirely as rainfall (27). It is uncertain how these values relate to conditions at sea.

Storm conditions include tropical storms and hurricanes. The difference between the two is purely a matter of intensity: winds from tropical storms range from 34-63 knots (17-32.5 m/sec), while hurricane winds exceed 64 knots. They both travel at a mean speed of 10 knots and usually come from the southeast. Within any 100 year period, 43 tropical storms and 26 hurricanes may be expected to occur near the incineration site.

3.3.4.1.3 Visibility--Visibility at the incineration site is good compared to the Gulf Coast shoreline. Visibility of less than 1 mile occurs only 0.23 percent of the time and less than 5 miles 2.6 percent of the time. These are annual percentages. Monthly data are presented in Reference 4, and will be useful once a definite schedule for incineration is finalized.

3.3.4.1.4 Relative humidity--Relative humidity at this site changes both seasonally and diurnally. Values are highest between January and May and reach their lowest points during July and August. Afternoons tend to have lower relative humidity than the mornings or nights. Extremes in relative humidity (greater than 90 percent) occur less than 15 percent of the time in the morning hours on an annual basis.

3.3.4.1.5 Ambient air temperatures--Ambient air temperature is reasonably warm all year round. Table 3 shows monthly averages for an annual period. The coldest month is January, and the warmest is August with mean monthly temperatures of 18.4°C and 29.1°C, respectively.

3.3.4.1.6 Atmospheric stability--No information regarding atmospheric stability could be found for the open ocean area of the Gulf of Mexico.

TABLE 3. MONTHLY AVERAGE TEMPERATURES FOR AN ANNUAL PERIOD IN THE GULF COAST INCINERATION SITE (5)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean Air Temperature (°C)	18.4	19.0	19.8	22.0	25.3	27.9	29.0	29.1	28.0	25.3	21.3	19.3

Stability refers to the mixing characteristics of the atmosphere and is an important parameter for considering the dispersion of pollutants. It is generally experesed in terms of stability classes, Class A being the least stable, and Class G being extremely stable. In lieu of more appropriate data, annual percent frequencies of the six stability classes are given for some major western Gulf Coast cities in Table 4. Stability Class D was used for plume dispersion modeling for the site (Appendix E). No data on inversion height are available.

3.3.4.2 Hydrological Conditions of the Gulf Coast Incineration Site--

Reference 4 presents an extensive discussion of the hydrological conditions in the Gulf Coast incineration site proposed for this disposal action. This section summarizes that research effort and presents that information which will aid understanding of potential environmental impacts of incinerating liquid silvex in the site.

The physical conditions of the ocean water, such as temperature gradient, currents, and waves, are important in determining the extent and rate of contaminant dilution. Chemical conditions, such as alkalinity, salinity, and dissolved oxygen, determine the ocean's ability to neutralize acid emissions and provide a base condition against which incremental impacts can be assessed.

3.3.4.2.1 Water masses--A water mass is defined as a large seawater parcel having unique properties of temperature, salinity, oxygen content, etc., characteristic of the water's location or place of origin. Five water masses are recognized in the Gulf and all occur within the site's water column. These water masses are vertically layered as follows: 1) Surface Mixed Layer, 2) Subtropical Underwater, 3) Oxygen Minimum layer, 4) Subantartic Intermediate Water, and 5) Gulf Basin Water. Each of these water masses can be

TABLE 4. ANNUAL PERCENT FREQUENCY OF STABILITY CATEGORIES FOR SOME GULF COAST CITIES (28,29)

	Pasquil Stability Constant					
	A	B	C	D	E	F&G
Mobile	1	5	11	45	16	22
Galveston*	0	5	15	58	22	--
Corpus Christi	0	2	8	61	15	14

*Based on only five stability classes.

distinguished in the Gulf by distinct values, gradients, or relative maxima or minima in specific parameters. The Surface Mixed Layer is the water mass which will be affected by at-sea incineration. It is generally characterized as the upper isothermal layer with temperature depending on the heat budget and by a salinity distribution depending on evaporation minus precipitation, runoff, and the horizontal advection of currents. The depth of this layer is approximately 75 meters (17).

3.3.4.2.2 Current patterns--The principal inflow of water into the Gulf of Mexico is from the Caribbean Sea through the Yucatan Strait. These waters are a mixture of South Atlantic water (transported northwestward by the Guiana and Equatorial current systems) with North Atlantic water (from the west Sargasso Sea) at a ratio of between 1:4 and 1:2 (30). Most of the outflowing water passes through the Florida Straits into the North Atlantic. The general flow of this Loop Current is clockwise.

The flow of surface water over the site varies only a small amount seasonally (4). The prevailing current is to the west or northwest. Data of the U.S. Naval Oceanographic Office (31) for the area around the proposed site show that from January to March, currents to the northeast quadrant occur with almost equal frequency as those to the western quadrant. Currents during the remainder of the year (April-December) show a strong affinity for westward flow. Current speed within the area is within a moderate range of 0.6 to 0.9 knot.

3.3.4.2.3 Waves--There has been no long term study of wave heights specifically within the site; however, the site is within National Climatic Center subregion 34 and adjacent to the northwest of Miniregion 341. Wave heights are generally greater from December to February and reach their low during June and July. Monthly wave height data are presented in Table 5 from Reference 4.

Wave direction in the site proposed for this disposal action corresponds closely to wind direction. According to U.S. Naval Oceanographic Office (30), throughout the year generally less than 10 percent of the waves have a westerly component. In April-September waves come mainly from the southeast quadrant. During October-March there is an increase from the northeastern quadrant with the southeastern component.

3.3.4.2.4 Water temperature--Throughout the year, variations in shelf surface temperature closely follow those of coastal air temperatures; however, farther offshore in the vicinity of the site, surface temperature corresponds with air temperature in the spring and summer but deviates somewhat in the fall and winter. This seasonal relationship between surface temperature and air temperature in the Gulf Coast site is given in Table 6 (4). From Table 6 it can be seen that the annual variation in average monthly surface temperature is some 10°C.

TABLE 5. WAVE HEIGHT BY MONTH FOR MINIREGION 341 (25-26°N, 92-93°W)(17)

Month	Median WH, m	WH 1.5 m, % Frequency	WH 2.4 m, % Frequency	WH 3.7 m, % Frequency	No. of Observations
Jan.	1.5	53.4	13.1	1.9	206
Feb.	1.0	49.5	11.2	2.1	180
Mar.	1.0	43.8	9.4	1.0	203
Apr.	1.0	41.1	6.8	.0	192
May	1.0	36.7	6.3	.5	207
June	1.0	16.5	.5	.0	212
July	0.5	12.2	.0	.0	180
Aug.	1.0	17.5	2.1	1.3	234
Sept	1.0	37.2	7.0	2.8	215
Oct.	1.0	37.7	7.9	3.9	228
Nov.	1.0	41.7	7.0	1.5	199
Dec.	1.0	45.1	8.3	1.0	193

TABLE 6. AVERAGE MONTHLY SEA SURFACE AND AIR TEMPERATURES FOR 5° (25°-30°N, 90°-95°W) NUMBER 50 OF MARSDEN SQUARE NUMBER 82 (4)

Month	Sea Surface	Air
Jan.	20.8	18.4
Feb.	20.6	19.0
Mar.	20.9	19.8
Apr.	22.2	22.0
May	25.3	25.3
June	28.1	27.9
July	29.6	29.0
Aug.	29.8	29.1
Sept.	29.0	28.0
Oct.	27.3	25.3
Nov.	24.4	21.3
Dec.	22.2	19.3

3.3.4.2.5 Salinity--Over the site the salinity of the surface waters is generally within the range of 36.0 - 36.5 mg/ml (parts per thousand) (4). Surface salinities may depart from this range since lower values (river influenced) have been detected in the Gulf as far south as the site; however, their influence is limited only to the upper part of the Surface Mixed Layer (4). In the vicinity of the site, vertical difference in salinity is only about 1.5 mg/ml from the surface to the bottom.

3.3.4.2.6 Dissolved oxygen--In the Surface Mixed Layer, dissolved oxygen concentration is fairly uniform and tends to be at saturation values determined by temperature. If the upper part of the water column is relatively stable (little mixing), a subsurface maximum in dissolved oxygen concentration is frequently present somewhere in the top 50 m as a result of oxygen production by photosynthesis. Below the photosynthetic zone, oxidation and respiration tend to reduce the dissolved oxygen content.

3.3.4.2.7 Acidity and alkalinity--The definition of pH is given by the following equation: $pH = -\log (H^+)$. The term alkalinity, as used by oceanographers, is defined as the number of milliequivalents (meq) of H^+ necessary to neutralize the anions of weak acids in one liter of seawater. Unfortunately, this usage of the term alkalinity is confusing because chemists have long used the same term to describe the OH^- concentration.

Since the H^+ concentration in seawater is involved in numerous equilibria, local, seasonal, and diurnal variations are often found. For example, one of the many factors on which pH is dependent is the amount of dissolved CO_2, which in turn depends on photosynthetic activity and thus on the amount of solar radiation. Therefore, in the assessment of environmental perturbations using pH measurements, it is necessary to have controls.

During the October-December 1974 monitoring of the incineration of organochlorine waste, approximately 158 pH samples and controls were analyzed from the proposed site (16). Except for one sample (pH 8.05) all were within the range of pH 8.2 - 8.4. In addition, diurnal variations were noted in the pH values. Alkalinity values determined from 23 samples collected at the proposed site during December 1974 ranged from 2.46 - 2.54 meq $(H^+)/l$.

The hydrological data available on the Gulf Coast incineration site show reasonably rapid mixing and thus dispersal and dilution of emission products from the incineration processes. As shown in section 4.1.1.4.2, at an assumed destruction efficiency of 99.9 percent, the concentrations 2,4-D; 2,4,5-TP; and TCDD in a 2-m mixing depth are expected to be 89 ng/l, 44 ng/l, and 13 fg/l, respectively. These concentrations are well below levels capable of causing environmental impacts.

3.3.4.3 Geological Conditions in the Gulf Coast Incineration Site--

Reference 4 presents an extensive discussion of the geological conditions in the Gulf Coast incineration site proposed for this disposal action. This section summarizes that research effort and presents that information which will aid understanding of the potential environmental impacts of incinerating liquid silvex in the site.

The site occupies an area of approximately 4900 square kilometers and is sited above the continental slope. Water depths within this perimeter range from near 1100 m to more than 1835 m. The seafloor gradient for this portion of the outer continental slope is somewhat uniform and gradual, 1:105 (4). The continental slope off Texas and Louisiana consists of at least two segments, a relatively steep lower slope known as the Sigsbee Escarpment and an irregular upper segment identified by its hummocky topography (31). The incineration site is positioned between these two major topographic features (4).

Bottom sediments of the continental slopes and shelves are characterized by complex patterns and mixtures of fine and coarse grained sediments (33). Calcareous remains of pelagic foraminifera are mixed with the sediments and, for a major part of the Gulf, tend to mask other sediment types by means of a thin cover of Globigerina ooze (34). Within the perimeter of the proposed incineration site this cover ranges in thickness from less than 10 cm to more than 40 cm. The carbonate of the sediment below the ooze cover in that region averages between 14 and 25 percent.

A major portion of the Gulf Coast site's bottom sediment contain heavy minerals from the Mississippi Province and the remainder, approximately one-third of the total area, has those of the Central Texas Province. In general, the basic sediment is clay particle in form except for a small region of "clay-silt-sand undifferentiated" in the southwestern corner. Sediment maps compiled by the U.S. Navy Oceanographic Office (31) also reveal a muddy sand in the southwest corner of the area.

3.3.4.4 Biological Conditions in the Gulf Coast Incineration Site--

Reference 4 presents an extensive discussion of the biota of the Gulf Coast incineration site proposed for this disposal action. Data include species enumerations, geographic distributions, seasonal cycles, primary production, and standing crop biomass. This discussion briefly summarizes that environmental impact statement and presents information which will aid understanding of the effects of at-sea incineration of liquid silvex on the marine ecosystem.

Based on all available data on phytoplankton and zooplankton at the incineration site, it is believed that the area is not as productive for these species as either the adjacent continental shelf or upper continental slope regions (4). Data from TerEco Corporation (35) show the relative abundance of phytoplankton cells collected within the limits of the study area to be from one to four orders of magnitude less than counts obtained from the vicinity of the continental shelf break and landward. Although there has been extensive sampling in the Gulf of Mexico for determination of phytoplankton standing crop and productivity and to a lesser extent for species distributions, only a few samples have been taken near the proposed incineration site. At several stations peripheral to the proposed site, surface chlorophyll-a values were low in August (0.11-0.18 mg/m^3), but slightly higher in February (0.18-0.32 mg/m^3). Chlorophyll-a values represent the amount of phytoplankton present in the water. It appears that the low primary productivity and chlorophyll-a values are related to low nutrient levels (4). Zooplankton of the incineration site consists almost wholly of oceanic forms. The site's distance from shore in conjunction with its water depth preclude most larval forms of commercially valuable continental shelf organisms such as shrimps and crabs. The numbers of zooplankton species and individuals present in the Gulf waters in the vicinity of the incineration site is very small in comparison to nearshore regions (4).

Nekton includes marine mammals, most fishes and cephalopod mollusks, and certain crustaceans which, because of their powerful swimming abilities, are able to move independently of water currents. These species are often able to escape most nets and other collection gear, hence knowledge of the geographic and vertical distribution patterns of nektonic species is often incomplete. The predominant components of this fauna are cephalopods, shrimps and fishes. Free swimming aquatic animals tend to concentrate in areas of abundant food supply. Since food supply is not abundant in the incineration site, it seems likely that a small number of the less important nektonic species inhabit the proposed incineration site waters as year-around residents, whereas many predatory species of commercial and sport interest (e.g., billfishes, tuna, dolphin) are probably only seasonal transients in the area, but little direct information on this point exists. Few larvae of commercially important shrimp species are present at the Gulf Coast incineration site, and larger nektonic species are not known to be abundant at the site. Neither the site itself nor the proximate area should support a productive fishery because of the absence of hard banks in that locale.

Neuston designates the fauna that live on, in, or just below the surface film of water bodies. The neuston are most likely to receive the highest exposure to emissions from at-sea incineration which settle on the surface and dissolve. The neuston is not clearly separated from the rest of the water column nor is it strictly separated from the plankton. Under certain conditions (e.g., during dim light, in turbid waters, and at night) the neuston community becomes less distinct or even almost identical to the zooplankton community of the adjacent strata. Examination of the catch of a typical neuston tow from the slope region of the Gulf of Mexico would reveal a fauna of varying complexity, dependent upon both time of day and season of collection. Early neuston samples from the northwestern Gulf were taken in order to ascertain the abundance of pelagic tar within a semi-enclosed sea that has extensive offshore oil production and tanker traffic (36). A more detailed study of neuston samples was conducted by TerEco Corporation during the fall of 1974 in conjunction with incineration activities over oceanic waters of the Gulf (35). These data are most valuable since that study offers the most complete enumeration of organisms collected during neuston tows from the proposed Gulf Coast incineration site currently available. Another pertinent study is that of Berkowitz (37) which also includes stations within the perimeter of the site. Based on his collection data and analysis, he states that "the neustonic zone of the open Gulf of Mexico is an impoverished area". A comparison of TerEco (35) data with findings of Zaitsev (38) or Hempel and Weikert (39) supports this conclusion.

Numerous sea bottom stations have been sampled for fauna population in the near vicinity of the incineration site by TerEco personnel; however, none were within its perimeter. The species present have been identified and enumerated, but these data have not been presented in published form. An additional study was conducted using sampling stations closely adjacent to the incineration site (shallower, deeper, and flanking). The samplings were obtained by means of either dredging or trawling during the period between 1969 and 1973. A total of 105 (4) species were identified, much less than the over 400 species found on the upper slope (40) and the number of species that has been collected from the continental shelf region (4). Sea bottom flora densities were observed to decrease with increasing depth.

Two bird migration routes may cause birds to pass near or over the incineration site proposed for this disposal action. Stevenson (41) lists 76 bird species that have been observed crossing the Gulf during the spring migration in parts of March, April, and May, or the fall period during parts of August, September, and October. In Louisiana, the earliest migrants appear in the fourth week of March and peak during early May when as many as 50,000 birds per mile of front per day have been observed (4).

3.3.4.5 Other Activities in the Vicinity of the Gulf Coast Incineration Site--

The Gulf Coast incineration site is far from normal shipping lanes, offshore exploration/drilling/production platforms, and commercial/recreational fishing grounds.

3.3.5 The North Atlantic Incineration Site

Figure 3 shows the relationship of the proposed North Atlantic incineration site and nearby land masses. This site, now being considered for designations by EPA (5), is outside the mid-Atlantic Bight and off Ocean City, MD. The site is centered 290 km from the nearest land.

It is a rectangle with corners at:

- 38° 00' N - 72° 30' W
- 38° 40' N - 72° 30' W
- 38° 40' N - 71° 59' W
- 38° 00' N - 71° 50' W

Subsequent sections describe the meteorological, hydrological, geological, and biological conditions in the North Atlantic incineration site.

3.3.5.1 Meteorological Conditions in the North Atlantic Incineration Site--

Meteorology of the North Atlantic incineration site has been summarized in the Draft Environmental Impact Statement evaluating this area as a potential incineration site (5). Primary data sources include the National Oceanic and Atmospheric Administration (NOAA), W.A. Brower (also of the NOAA), and the U.S. Department of Commerce. These data are assumed to be an adequate representation of available information for this site. Phenomena discussed in the following paragraphs include winds, storms, precipitation, visibility, relative humidity, ambient air temperature, and atmospheric stability. Data on these parameters are incorporated by reference to the North Atlantic draft EIS, Reference 5.

3.3.5.1.1 Winds--During the winter months, winds blow predominantly from the North and Northwest points of the compass. Mean wind speeds for the winter months range between 17 and 19 knots (8.5-9.5 m/sec). During the milder summer months, winds tend to blow more from the south, with mean wind speeds ranging between 11 and 16 knots (5.5-8 m/sec).

3.3.5.1.2 Precipitation and storms--Absolute amounts of precipitation over the open water near the burn site are not known. The annual average for precipitation over the coast is 100 cm/yr, which may have some applicability to the offshore areas since fronts usually move from west to east. A majority of precipitation falls between November and April and is associated with the widespread storms experienced during this period. A substantial amount of snow is observed between the months of December and March. Brief, localized thunderstorms are characteristic of the summer months.

A total of 45 tropical cyclones have passed through the site between the years 1899 and 1976. Of these, 21 were hurricanes, and 24 were tropical storms of lesser magnitude. The highest percentage of hurricanes occur in August, but these storms have also been recorded between the months of June and December.

3.3.5.1.3 Visibility--Visibility reduction from haze or fog occurs most frequently in late spring and early summer. This condition is usually most severe in the morning hours, and visibility increases toward noon. During this period, visibility is less than five miles 20 percent of the time. During the autumn and winter, this value is only 10 percent. Monthly visibility data are presented in Reference 5.

3.3.5.1.4 Relative humidity--Relative humidities in this area tend to be higher in the summer because of the prevailing southerly winds during this period. The average annual relative humidity is 81.2 percent. The peak occurs in June at 86.5 percent and the minimum occurs in November at 76.6 percent.

3.3.5.1.5 Ambient air temperature--Weather in this region is dominated by cold polar air two months out of the year and by warmer tropical Atlantic air the remaining ten. Table 7 shows monthly averages for an annual period. The coldest month is February, and the warmest is August with mean monthly temperatures at 6.4°C and 24.0°C, respectively. Low air temperatures during winter and spring may complicate or even preclude stack gas monitoring during incineration due to problems associated with maintenance of required temperatures in sampling lines and freezing of impinger solutions.

TABLE 7. MONTHLY AVERAGE TEMPERATURES FOR AN ANNUAL PERIOD IN THE NORTH COAST SITE (5)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean Air Temperature (°C)	7.0	6.4	7.5	10.5	14.1	19.6	23.5	24.0	21.6	18.3	13.5	9.2

3.3.5.1.6 Atmospheric stability--No information regarding atmospheric stability could be found for the open ocean area of the North Atlantic. For lack of any better data, stability occurrences are given in Table 8 for two east coast cities in the vicinity of the site. A short discussion of stability class information is given in section 3.1.4.1.6 describing meteorology for the Gulf Coast incineration site. No data on inversion height are available.

3.3.5.2 Hydrological Conditions in the North Atlantic Incineration Site--

Reference 5 presents an extensive and detailed discussion of the hydrological conditions of the proposed incineration site. This discussion is extracted from that work and presents the information pertinent to understanding the potential effects of incinerating liquid silvex in this site.

NOAA has characterized the physical oceanographic environment in the region of the proposed incineration site as being extremely complex and variable in all but the near-bottom water (43). The surface waters are of the most concern here since they would be the most affected by the proposed incineration. Physical conditions of the ocean water, such as temperature gradient, currents, and waves are important in determining the extent and rate of contaminant dilution. The chemical conditions such as alkalinity, salinity, and dissolved oxygen determine the ocean's ability to neutralize acid emissions and provide a base condition, against which incremental impacts can be assessed.

3.3.5.2.1 Water masses--As defined previously, a water mass is a large seawater parcel having unique properties of temperature, salinity, oxygen content, etc., characteristic of the water's location or place of origin. Three water masses may be present at the proposed incineration site: 1) Slope

TABLE 8. ANNUAL PERCENT FREQUENCY OF STABILITY CATEGORIES FOR TWO EAST COAST CITIES IN CLOSE PROXIMITY TO THE NORTH ATLANTIC INCINERATION SITE (41)

City	Pasquill Stability Category					
	A	B	C	D	E	F
New York	0	3	10	67	13	6
Philadelphia	0	5	11	51	14	18

water, 2) Shelf water, and 3) Gulf Stream water. Normally the surface layer of the site is Slope water, which lies between fresher Shelf water to the west and more saline Gulf Stream water to the east. However, conditions often change, periodically allowing Shelf water to enter the site from the west, or permitting Gulf Stream water (in the form of southerly-moving Gulf Stream eddies) to be present about 20 percent of the time.

Slope water is a highly complex, dynamic body of water representing an area of mixing between Shelf water, which bounds it on the north and west, and the Gulf Stream, which forms the southern boundary. These boundaries (frontal zones) are not stationary but migrate seawards and landwards when the Gulf Stream shifts its axis during meanderings.

The Gulf Stream frequently meanders in such a way that anticyclonic (clockwise) loops of current are formed. Occasionally, these loops detach and form separate entities, known as eddies. The eddies are rings of Gulf Stream water surrounding a core of warm Sargasso Sea water (which originates to the east of the Gulf Stream) or trapped Gulf Stream water. Great amounts of this water may be advected to depths as great as 800 to 1,000 m (43). After detachment, the eddies may migrate into the Slope water region, usually in a southwesterly direction. In addition, the eddies may interact with Shelf water, causing considerable disturbances in the water within the proposed site region. Water mixing is thus reasonably rapid, and dilution and dispersal of combustion products and unburned silvex components will also be reasonably rapid.

3.3.5.2.2 Current patterns--Well-defined circulation patterns are unknown in surface layers of the Slope water regions in which the proposed incineration site is located (44). Paucity of long-term current records, in addition to large natural variabilities, limit the usefulness of estimates of mean currents for this region. The westward-flowing Labrador Current loses its distinctiveness somewhat west of the Grand Banks. Current measurements have been made by several researchers in the region of the Shelf break and Slope south of New England (45-47). The mean currents in this area are generally of the order of 10 to 20 cm/sec westward, following the bottom bathymetry. This direction is similar to the direction taken by currents over the Continental Shelf.

The Oceanographer of the Navy (48) reported a mean surface current speed of 25 cm/sec near the proposed incineration site. The direction of the flow was either east-northeast or south-southwest. No other current measurements for the region of the proposed incineration site have been reported.

3.3.5.2.3 Waves--Brower (49) compiled wave information for the New York Bight coastal region, the 106-mile Ocean Waste Disposal Site, and adjacent waters. Observations for the period between 1949 and 1974 are discussed below and presented in Table 9. In general, wave heights increase with distance from shore throughout the year, and the differences in heights are smaller in summer. The average frequency of observations of hazardous waves (wave heights greater than or equal to 3.5 m) is 5 to 6 percent from December until March. While the frequency of hazardous waves at two light stations near the New Jersey coast varies from less than 0.5 percent in summer to approximately 1 to 2 percent in winter, the frequency seaward at the proposed incineration site and surrounding area varies from about 1 percent in summer to more than 10 percent from November until March, with a peak of 13 percent in January and February. The frequencies tend to increase northwest to southeast across the Bight throughout the year.

3.3.5.2.4 Water temperature--The waters in and around the proposed site are subject to sudden changes in temperature occurring between Shelf water and the surface Slope water. Shelf water is always much colder than Slope water during winter, but during the warmer months of the year, peak surface

TABLE 9. MONTHLY WAVE HEIGHT FREQUENCY FOR THE PROPOSED NORTH ATLANTIC INCINERATION SITE REGION (46)

Month	WH 1.5 m, % Frequency	WH 2.5 m, % Frequency	WH 3.5 m, % Frequency	No. of Observations
Jan.	33.5	70.7	12.7	355
Feb.	36.2	68.1	13.1	243
Mar.	38.8	75.3	11.0	329
Apr.	48.7	82.7	6.6	392
May	68.2	90.1	1.9	314
June	75.9	95.3	1.0	382
July	78.6	95.0	0.9	274
Aug.	66.3	97.6	0.7	290
Sep.	60.0	89.5	3.5	401
Oct.	50.2	80.2	5.3	337
Nov.	39.8	79.2	10.1	409
Dec.	38.5	78.5	10.3	377

temperatures of Shelf water exceed those of Slope water. The horizontal temperature gradients between the two water masses become less marked only during periods of warming and cooling. The water masses are then best distinguished by salinity differences (50). Figure 6 shows average monthly surface temperatures.

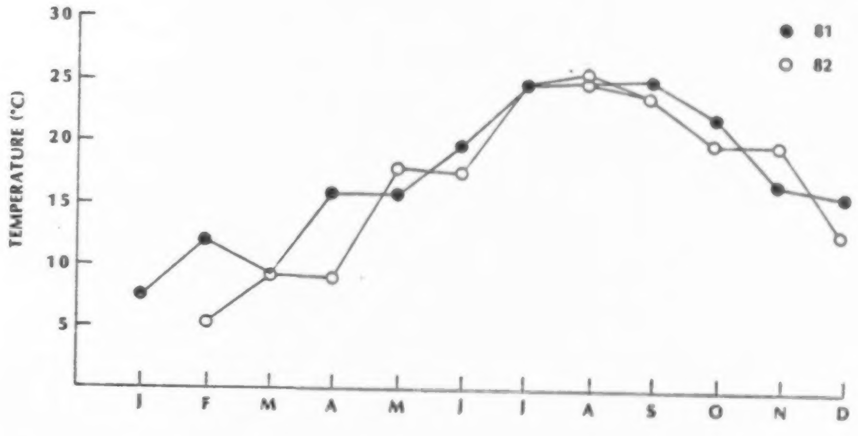


Figure 6. Average monthly sea-surface temperatures for subsquares 81 and 82 in Marsden Square 116, near the proposed North Atlantic incineration site (48).

3.3.5.2.5 Salinity--The waters in and surrounding the proposed incineration site are subject to sudden changes in salinity which may occur between Shelf and surface Slope waters. Shelf water is always fresher than Slope water during winter. During the warmer months, the two water masses are best distinguished by temperature differences, but during periods of warming and cooling, the water masses are best distinguished by salinity differences (50). Warsh (51) found that the range of surface salinity was quite variable and was dependent on the water mass present (Shelf, Slope, or Gulf Stream) within each square. Average surface salinities range from 32.70 to 35.57 mg/l in the vicinity of the site.

3.3.5.2.6 Dissolved oxygen--Oxygen is a fundamental requirement for marine life. It is produced during photosynthesis in the sunlit zone, usually less than 100 m in depth, and is used by animals, plants, some bacteria in respiration, and in the decomposition of organic matter.

Warsh (51) summarized historical data for the water within, and adjacent to the 106-mile ocean waste disposal site. Within the site, monthly average oxygen values at the surface range from 4.9 ml/l (approximately 104 percent saturation) in August to 7.5 ml/l (approximately 113 percent saturation) in April.

3.3.5.2.7 Acidity and alkalinity--Seawater pH ranges from 7.8 to 8.4, averaging 8.2. This small range is maintained in seawater by buffering from chemical systems, such as the carbon dioxide-bicarbonate-carbonate complex. Buffering is the ability of a substance in solution to neutralize either acids or bases while maintaining the original alkalinity of the solution. The buffering capacity or alkalinity of seawater results from the presence of acid-neutralizing bicarbonate (HCO_3^-) and carbonate ($CO_3^=$) ions. Alkalinity is important for fish and other aquatic life because it buffers pH changes which occur naturally as a result of photosynthetic activity. Components of alkalinity (carbonate and bicarbonate) have been shown to complex some toxic heavy metals and reduce their toxicity. Alkalinity is increased by the dissolution of calcium carbonate already present in seawater and that which enters by runoff. Decomposition of organic matter in seawater consumes oxygen and produces carbon dioxide, which reacts with water to form carbonic acid and lowers the pH. Thus, pH and oxygen profiles in the sea generally parallel one another since the pH is lowered as the oxygen concentration decreases (5).

Hausknecht and Kester (52) reported pH values for samples taken during the summer at the nearby 106-mile ocean waste disposal site. At the surface, the average pH was 7.9.

3.3.5.2.8 Summary--The hydrological data available on the North Atlantic incineration site show that reasonably rapid mixing of surface ocean waters will disperse and dilute emission products from the incineration process. As shown in section 4.1.1.4.2, at an assumed destruction efficiency of 99.9 percent, the concentrations of 2,4-D; 2,4,5-TP; and TCDD in a 2-m mixing depth are expected to be 89 ng/l, 44 ng/l, and 13 fg/l, respectively. These concentrations are well below levels capable of causing environmental impacts. Wave heights in the North Atlantic incineration site are generally higher than in the Gulf Coast site, a negative factor for at-sea incineration.

3.3.5.3 Geological Conditions in the North Atlantic Incineration Site--

Reference 5 presents an extensive discussion of the geological conditions in the proposed North Atlantic incineration site. This section briefly summarizes that research effort and presents that information which will aid understanding of the potential environmental impacts of incinerating liquid silvex in the site.

The North Atlantic incineration site is outside the mid-Atlantic Bight, off Ocean City, MD, and is over the Continental Rise off the northwest Atlantic Ocean. The center of the site is 290 km from the nearest land mass. Water depths range from 2,400 m in the northwest corner of the proposed site to 2,900 m along the east side of the proposed site.

Four submarine canyons incise the Continental Slope near the proposed site. In addition, numerous smaller canyons exist in the Slope region west of the proposed site. The massive Hudson Canyon system (100 km north of the proposed site) extends from the New York Bight Apex to the edge of the Continental Slope.

The Recent Age sediments deposited on the Continental Slope and Rise are primarily silt and clay (5). Most of the sand in this region is biogenic in origin, although patches of terrigenous sand occur in the axes of some canyons (5). The sediments on the Slope tend to be olive or brown in color, which may be a function of the high oxygen content of the Slopr water and iron staining. Calcium carbonate is a major component of Slope sediments, making up as much as 75 percent of the sediments in some areas (5).

The lower Continental Slope and Rise lying below 3,500 m have numerous current-induced features, formed by the southwestward-flowing Western Atlantic Undercurrent (52). The lower Continental Slope and Rise may be thick prisms of deep sea turbidities, clays, and slump deposits (53).

3.3.5.4 Biological Conditions in the North Atlantic Incineration Site--

Reference 5 presents an extensive discussion of biological conditions in the Atlantic incineration site proposed for this disposal action. Data include species enumerations, geographic distributions, seasonal cycles, and standing crop biomass. This section briefly summarizes that research effort and presents information which will aid understanding of the effects of at-sea incineration of liquid silvex on the marine ecosystem.

Few phytoplankton investigations have been performed in the region of the proposed incineration site. Summer was the only season in which sampling was performed. Phytoplankton abundance at the nearby 106-mile site varies with depth from 100 to 100,000 cells/liter with the phytoplankton much more abundant in the upper 20 m than at 25 to 50 m depths. Abundance was greatly reduced at greater depths. Phytoplankton populations at the 106-mile site were found to be composed of a mixture of coastal and oceanic species because of the site's location in a transitional area between coastal and oceanic waters and in the path of Gulf Stream eddies (5). Phytoplankton cell densities were also found generally to decrease with increasing distance from land. Maximum cell densities were observed in December, and minimum in July (5).

Major changes in species composition occur inshore to offshore. Dominant coastal species require relatively high nutrients to sustain high bloom populations and are subject to wide seasonal variations in abundance and diversity. In contrast, oceanic waters under some influence of the Gulf Stream carry a phytoplankton community which requires somewhat lower nutrients and are subject to reduced or dampened seasonal variations in abundance.

Zooplankton studies performed at the nearby 106-mile ocean dump site have confirmed the variable and transient nature of water masses in the area of the proposed incineration site. The composition of the zooplankton population was found to be the result of mixing of the Shelf, Slope, and Gulf Stream water masses. Copepod populations in Shelf waters were dominated by boreal assemblages characterized by high abundance and few species, while the Slope and Rise water masses contained a mixture of subtropical and boreal assemblages which results in lower abundance of individuals and a greater number of species. The seasonal zooplankton biomass range was 7.7 to 1780 ml/1000 m^3 in summer and 5.5 to 500 ml/1000 m^3 in winter (5).

Nekton schools are highly mobile, migrate over long distances, and have unknown depth ranges. Data on these organisms are globally limited and qualitative. During the day most fishes are found at considerable depths (greater than 200 m), but at night large numbers of the population migrate to the upper layers of the water column. At these depths any contaminants entering the ocean environment from the surface will be highly diluted. Small numbers of larger species contribute greatly to the total fish biomass. Krueger, et al. (54) concluded that the 106-mile site, in summer and winter, was characterized by Slope water fish fauna, upon which a Northern Sargasso Sea fauna (presumably transported to the site by warm-core eddies) was super-imposed. The Sargasso Sea species, present in summer, were less abundant in winter, suggesting that their presence and abundance are dependent upon eddy size, age, and/or core temperatures.

The sea bottom biota of the proposed site lie at abyssal depths in the lower mid-Atlantic Continental Slope and in the Continental Rise. Research on the faunal assemblages of the Continental Slope commenced only recently, thus there are little data concerning Continental Slope sea bottom populations. Substantial evidence exists, however, that the major components of faunal assemblages at various Slope depths do not change significantly throughout the mid-Atlantic and neighboring areas (5,55,56). Deep sea nutrition is one of the most important factors influencing the distribution of sea bottom animals in the site regions. Larsen and Chenoweth (55) believe that the lower levels of available organic carbon at greater depths are key factors determining faunal biomass and densities at these depths.

It is generally recognized that the food supply for these plants originates from shallower areas (5). Surveys of the sea bottom biota in the 106-mile site have found no species of present commercial importance and only a few of potential importance. The shellfish commonly harvested on the adjacent shelf, including the surf clam, sea scallop, and southern quahog, do not extend their ranges to the Continental Slope. The lobster is presently fished in canyon and Shelf areas to the north and west (57). The red crab is a potential commercial species of the mid-Atlantic but is found only in Slope areas to the north and west (57,58). No fishes of commercial importance are presently being harvested from the vicinity of the proposed site, and only a few potential species have been found in the region.

Thirty-nine species of marine birds are known to frequent the off-shore and coastal waters of the mid-Atlantic Bight (5). The abundances range from occasional to common and most often exhibit migratory or seasonal variability. A few species are thought to be rare or endangered in some parts of their range; however, none are considered endangered species in the region of the mid-Atlantic Bight. For all reported species, winter observations show that few birds frequent the proposed site region between November and March. The summer months between April and October produce the greatest number of bird sightings. May and June sightings generally produce the highest average counts.

3.3.5.5 Other Activities in the Vicinity of the North Atlantic Incineration Site--

The North Atlantic incineration site is far from normal shipping lanes, offshore exploration/drilling/production platforms, and commercial/recreational fishing grounds.

3.3.6 Ship Cleaning Operations

Ship cleaning and rinsate incineration will take place at sea in the incineration site. Thus, the descriptions of the environments affected by incineration at sea will apply to the ship cleaning operations as well.

3.4 LAND-BASED INCINERATION

This section describes the environment potentially affected by the land-based incineration alternative. Because a suitable facility has not been selected, no details on the environment around the facility can be provided. The types of data which would be required to properly characterize the land-based incineration site are described in this section. For the meteorological description of the site, a specific example has been used.

3.4.1 Meteorological Conditions

The Rollins Environmental Services, Inc., incineration facility located in Deer Park, Texas, is a typical example of a land-based incineration site. Since this site is in close proximity to Houston, meteorological data from Houston were considered representative. Most of the data were obtained directly from the National Climatic Center (29,59). The phenomena discussed below include winds and storms, precipitation and cloud cover, visibility, relative humidity, ambient air temperature, and atmospheric stability.

3.4.1.1 Winds and Storms--

Prevailing winds in the Houston area are from the south or southeast, except in January when frequent invasions of polar air cause prevailing northerlies. The range of wind speeds is from 3.8 m/sec in August to 5.8 m/sec in April, with an annual average of 4.8 m/sec. The strongest wind recorded since 1969 had a speed of 20.7 m/sec, and occurred in July of that year. Winds are rarely high enough to cause damage, but both thundersqualls and tropical storms occasionally pass through the area.

3.4.1.2 Precipitation and Cloud Cover--

The occurrence of precipitation is rather evenly distributed throughout the year. Precipitation is almost always as rainfall, with about 75 percent of all years having between 75 cm and 150 cm. Annual average precipitation is 120 cm. Thunderstorms occur up to 12 times a month in the summer, but only 2 or 3 times a month in the winter. Snow does occur on rare occasions. The record dates back to 1895 when 50 cm of unmelted snow was measured.

Cloud cover is maximum between December and May, with the clearest days occurring in October and November. The percent of the maximum possible solar radiation reaching the surface ranges from 69 percent in the summer to 46 percent in the winter.

3.4.1.3 Visibility--

Ground and advective fogs are fairly common because of the proximity of the site to Galveston Bay and the numerous small streams and bayous in the area. Heavy fog occurs on about 16 days out of the year, and light fog occurs on about 62 days, but these incidences are known to increase outside of the city.

3.4.1.4 Relative Humidity--

Relative humidity is generally greatest shortly before sunrise. On a seasonal basis, higher values are experienced in the summertime. Annual average relative humidity is approximately 80 percent.

3.4.1.5 Ambient Air Temperature--

Winds from the Gulf moderate temperatures in the Houston area. Temperatures go below freezing an average of 15 days per year on the south side of the city and 23 days on the north side. Most of these freezing temperatures last only a few hours. On average, the first day of below freezing temperature is 11 December, and the last day is 5 February. Table 10 gives mean air temperatures for a 39 year period (1939-1978).

3.4.1.6 Atmospheric Stability--

An annual summary of atmospheric stability class category occurrences for the Houston area is presented in Table 11. It can be seen that the "D" stability category is the most prevalent. This is the stability class referring to a neutral atmosphere. No data on inversion height are available.

3.4.2 Hydrological Conditions

No data are available at this time. Pertinent information would be the same as noted in section 3.3.1.2.

3.4.3 Geological Conditions

No data are available at this time. Pertinent information would be the same as noted in section 3.3.1.3.

3.4.4 Biological Conditions

No data are available at this time. Pertinent information would be the same as noted in section 3.3.1.4.

TABLE 10. MEAN AIR TEMPERATURE IN HOUSTON FOR A 39 YEAR PERIOD (59)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
°C	10.2	12.3	16.3	19.8	23.4	26.6	28.0	27.6	25.4	20.6	15.3	12.4
°F	50.4	54.1	61.4	67.7	74.1	79.9	82.4	81.7	77.8	69.1	59.6	54.4

TABLE 11. ANNUAL PERCENT FREQUENCY OF STABILITY CATEGORIES FOR HOUSTON (26)

Stability Class	Annual
A	1
B	8
C	11
D	41
E	10
F	29

3.4.5 Other Activities in the Vicinity of the Site

The entire land-based disposal action - from decanning through incineration - will likely be carried out on the same industrial site. Other activities will probably be in progress on the site, including shipping and receiving of wastes other than silvex herbicides, tank and drum storage, and chemical processing. These factors would tend to increase the risk of accidental exposure of workers not involved in the silvex disposal action to the herbicide. The proximity of the facility to other industrial or residential areas increases the potential risk to the public in the event of accidents or malfunctions.

4. ENVIRONMENTAL CONSEQUENCES

Environmental consequences of the proposed and principal alternative actions are described in this chapter. For both at-sea and land-based incineration alternatives, the incineration operation will destroy in excess of 99.9 percent of the liquid silvex formulations. Analyses of stack samples taken during the at-sea incineration of Herbicide Orange did not detect any unburned n-butyl esters of 2,4-D or 2,4,5-T. Destruction efficiencies were reported as greater than 99.999 percent (14).

Impacts of not only unburned liquid silvex components but also major combustion products are considered. These products are: water, heat, hydrogen chloride, carbon dioxide, carbon monoxide, and particulates. In the case of at-sea incineration, these components will be discharged directly into the atmosphere. In the case of land-based incineration, the combustion effluent will be passed through a scrubber which will remove in excess of 99 percent of the HCl and the bulk of generated particulates.

Also considered in Chapter 4 are unavoidable adverse environmental impacts of the proposed and principal alternative actions, the relationship between the proposed action and the maintenance and enhancement of the long-term productivity of the environment, and irreversible and irretrievable commitments of resources involved in performing the proposed action.

4.1 ENVIRONMENTAL IMPACTS

Section 4.1 describes the environmental impacts of the proposed and principal alternative actions. Appendix E presents details of atmospheric dispersion modeling for both the at-sea and land-based incineration alternatives. Modeling was performed for 2,4-D and 2,4,5-TP equivalents, HCl and TCDD. Descriptions of the environmental fate of TCDD and the isooctyl esters (IOE) and butyl propyl esters (BPE) of 2,4-D and 2,4,5-TP given below are adapted from two extensive studies performed by the U.S. Air Force (USAF), References 8 and 60. The USAF studies concerned the n-butyl esters (NBE) of 2,4-D and 2,4,5-T. It is assumed that the behavior of the IOE and BPE of 2,4-D and 2,4,5-TP is similar to that of the NBE of 2,4-D and 2,4,5-T, except as noted. Descriptions of the impacts of these compounds in air, water, land, flora, and fauna are given in subsequent sections.

Aqueous solubilities of the NBE of 2,4-D and 2,4,5-T are very low. In artificial seawater, the solubilities for 2,4-D and 2,4,5-T NBE were 2.0 and 1.8 mg/l, respectively (8). Because of higher molecular weights and longer hydrocarbon side chains, the solubilities of BPE and IOE of 2,4-D and 2,4,5-TP are expected to be somewhat lower. No value for the solubility of TCDD has been found, but it is expected to be much less than that of the esters.

The esters are readily hydrolyzed, biogenically or abiogenically, in water, seawater, and soils. Thus, the behaviors of the pure acids and their salts are also pertinent and will be discussed in following paragraphs. The USAF found the half life of NBE 2,4-D to hydrolysis to be 15 hours (8) in neutral seawater. The hydrolysis half life of NBE 2,4,5-T was somewhat longer. In still waters the USAF found that the rate of hydrolysis was probably faster than the rate of dissolution, so that lethal concentrations were never attained.

Crosby (61) reviewed the nonbiological degradation of phenoxy herbicides in soil and reported that the isopropyl, butyl, and isooctyl esters of 2,4-D had a half life of about 100 hours in neutral soil water. Hydrolysis was almost instantaneous in the presence of base or a suspension of several soils at pH 7.0-7.5. Many of the phenoxy herbicides readily undergo oxidation, reduction, and substitution in aqueous solutions when activated by sunlight in air. Degradation in sunlight and water of 2,4-D is fairly rapid; degradation under similar conditions of 2,4,5-T is slow.

Evidence summarized by the USAF shows that phenoxy herbicides are rapidly decomposed in soils (60). The modes of decomposition are so numerous that 2,4-D is classed as a non-persistent herbicide because its estimated half life in soil is < 0.5 months. On the other hand, 2,4,5-T is classed as slightly persistent because its estimated half life is from 0.5 to 1.5 months. TCDD is more persistent in soils. Kearny et al. (62) determined a half life of TCDD in soil of about 1 year. They also found that TCDD was neither biosynthesized by microorganisms nor readily degraded by microorganisms. The USAF reported half lives for TCDD in soil of 320 and 230 days in two different locations (Utah and Florida) where massive quantities of Herbicide Orange were injected into soils.

In a significant study on the environmental fate of TCDD, Crosby and Wong (63) found that herbicide formulations containing known amounts of TCDD and exposed to natural sunlight on leaves, soil, or grass lost most or all of the TCDD in a single day, principally by photochemical dechlorination. Despite the known stability of pure TCDD, it is not stable in thin films in sunlight in the presence of hydrogen donors. Nash and Beall (64) concluded from their studies of the fate of TCDD in a microagroecosystem that, once TCDD was volatilized, it dechlorinated in the direct sun or apparently even in outdoors shade. They concluded further that TCDD was sensitive to photodechlorination in the vapor phase even in the absence of ultraviolet radiation.

Acute toxicities are generally reported as "LD_{xx}" (Lethal Dose) for terrestrial animals and "LC_{xx}" (Lethal Concentration) for aquatic animals. The "xx" is the percentage of animals killed by the dose to which they were exposed. Acute toxicity studies show that esters of 2,4-D and 2,4,5-T are not particularly toxic. Excretion of these herbicides is very rapid in most mammals and in other animals with well developed renal function. Literature surveyed by the USAF (60) showed LD_{50} values for 2,4-D (acid and esters) ranging from 100 mg/kg (dog) to 2000 mg/kg (rat, guinea pig, cattle). For 2,4,5-T (acid and esters), LD_{50} values ranged from 100 mg/kg (dog) to 940 mg/kg (mouse). TCDD is one of the most potent small-molecule toxins known. Literature surveyed by the USAF showed LD_{50} values ranging from 0.6 μg/kg (guinea pig) to 300 μg/kg (dog). Subacute and no-effect doses are smaller for all 3 compounds.

The behavior of chlorophenoxy herbicides in non-mammalian aquatic systems is quite different than the behavior described above for terrestrial animals, and these herbicides have a greater toxic potential. First, the route of entry into the aquatic animal is usually different: the herbicide is distributed throughout the total aquatic environment. Second, non-mammalian aquatic animals generally do not have highly developed renal systems which promote rapid excretion of the herbicides. Toxicity testing of aquatic animals is usually conducted by placing the animal in a known concentration of the toxicant. Thus, the actual dose to each animal is not generally known, and toxicities are often reported as LC_{xx}.

Toxicities of the chlorophenoxy herbicides to aquatic animals vary considerably with numerous factors, such as water chemistry, temperature, and the particular acid, salt, or ester form administered. Species susceptibility varied greatly. The USAF found (8) that the acids of 2,4,-D and 2,4,5-T were considerably less toxic than the esters. Fresh water bioassays using fat head minnows resulted in 48 hour LC_{50} values of 2.8 and 5.0 ppm for 2,4-D and 2,4,5-T, respectively. This result was obtained in a still, unstirred and unaerated system in which the rate of hydrolysis to the acids was faster than the rate of dissolution of the esters. In a stirred, aerated system, the 48 hour LC_{50} values for the fat head minnows were 270 and 330 ppm for NBE 2,4-D and 2,4,5-T, respectively. In salt water shrimp, the USAF found 48 hour LC_{50} values of 5.6 ppm for NBE 2,4-D and 33 ppm for NBE 2,4,5-T (8). The USAF reported on a study of fresh water crustaceans: 48 hour LC_{50} values were: seed shrimp = 0.32 ppm, scud = 2.6 ppm, sowbug = 2.2 ppm, glass shrimp = 2.7 ppm, crayfish > 100 ppm for the propyleneglycolbutyl ether of 2,4-D.

Walsh (65) found that oxygen production was decreased by 50 percent when four species of marine algae were exposed for a period of 90 minutes to 50-60 ppm of 2,4-D acid, 100-200 ppm of the butoxy ethanol ester of 2,4-D, and 50-150 ppm of 2,4,5-T acid. He found very similar results when measuring the effects of the same herbicides on growth rates of the same four algal species. Algal bioassays conducted by the USAF Environmental Health Laboratory at Kelly AFB showed that Herbicide Orange inhibited growth of marine algae at concentrations of 50-100 ppm (8).

The following conclusions regarding the fate of 2,4-D and 2,4,5-T esters and TCDD in the environment are pertinent to considering the potential environmental impacts of the proposed action (8):

- 2,4-D and 2,4,5-T esters do not accumulate in any compartment of the biosphere.

- 2,4-D and 2,4,5-T esters are rapidly hydrolyzed in water to the acids, causing a decrease in toxicity because the acids are much less soluble.
- There is no evidence that TCDD accumulates in air, water, or plants. TCDD is known to accumulate in some organisms but not to be biomagnified.
- TCDD is rapidly degraded in the presence of sunlight and hydrogen donors (e.g., kerosene). There is evidence that TCDD is photochemically dechlorinated in the vapor phase even if a hydrogen donor is not present.

4.1.1 Impacts of Incineration At Sea

There is now a considerable body of technical literature demonstrating the minimal environmental impacts of at-sea incineration of organochlorine wastes. Wastler, et al. (16) reported on extensive monitoring by EPA during incineration of organochlorine wastes in the Gulf Coast incineration site in 1974. This monitoring effort: 1) did not detect pH or chlorine concentration changes, 2) did not detect organochlorines in the seawater, 3) did not find significant increases in trace metal concentrations, 4) did not find deleterious effects from analyses of 200 plankton, phytoplankton, chlorophyll-a, and ATP samples, 5) showed greater than 99.9 percent destruction efficiency, and 6) found no adverse effects on migratory birds. Clausen, et al. (15) reported results of EPA-sponsored monitoring during burning of organochlorine wastes in the Gulf Coast incineration site in early 1977. They reported destruction efficiencies greater than 99.99 percent, and found only traces of some waste constituents in the stack emissions. Ackerman, et al. (14) reported on the at-sea incineration of Herbicide Orange in a Pacific Ocean incineration site in the Fall of 1977. Their results showed destruction efficiencies for the butyl esters of 2,4-D and 2,4,5-T were in excess of 99.999 percent. Neither of these two major Herbicide Orange constituents was detected in any combustion effluent sample. Ackerman (13) reported on TCDD destruction efficiencies during the at-sea incineration of Herbicide Orange. A compound which might have been TCDD was detected in several of the stack samples, but positive identification was equivocal because high resolution mass spectrometry was not employed and because of high levels of interferences. TCDD destruction efficiencies, based on detection limit subject to interferences, exceeded 99.9 percent.

Ackerman, et al. (11) reported on recent tests of combustion gas and waste flow rate measurement systems onboard the M/T Vulcanus. Both systems functioned well over a period of several months. Average combustion efficiency for the first and second burns was 99.983 ± 0.023 percent and for the third burn was 99.983 ± 0.017 percent, both better than the 99.95 ± 0.05 percent required by the London Dumping Convention regulations.

There have also been a number of studies on at-sea incineration of organochlorine wastes sponsored by European governments. Appendix N of the USAF final environmental impact statement (8) for the disposal of Herbicide Orange is composed of six such studies, all attesting to the lack of significant environmental imapcts from incineration at sea.

For the proposed action of incineration at sea, a worst case set of parameters was chosen for modeling (3). These parameters were, per incinerator: 5776 kg/hr liquid silvex feed rate, 70,000 dry m^3/hr air feed rate, and 3 percent excess oxygen. This set of parameters was the lowest air-to-feed ratio considered for equilibrium combustion product distribution calculations presented in Reference 3. Assuming 99.9 percent destruction efficiency, maximum emission rates for major combustion products under the worst case assumptions are given in Table 12. Appendix E.5 presents details of these calculations.

While emissions of heat, particulates, and CO_2 are considerable, they will have no significant impact on the environment, for the sea and atmosphere will readily absorb these quantities.

The maximum downwind concentration of CO was calculated to be 0.7 ppbv (Appendix E.5.8), at least 3 orders of magnitude below the ACGIH TLV of 50 ppmv or ambient air quality standards of 9 ppmv for 8 hours once per year, or 35 ppmv for 1 hour once per year (40 CFR 50.8). Thus, taking a conservative approach, the expected carbon monoxide emissions from the ship will cause no adverse environmental impacts. Impacts of 2,4-D; 2,4,5-TP; TCDD; and HCl are considered in subsequent sections.

It was noted in Appendix D that incinerator ships have the capability for emergency jettisoning of the cargo if the safety of the crew or vessel is threatened. Also, there is a possibility of the vessel's sinking while

TABLE 12. WORST CASE MAXIMUM EMISSION RATES

Product	Rate/Hour	Rate/Day	Emission Concentration
2,4-D equivalent	1.63 kg	39.1 kg	11.6 mg/m^3
2,4,5-TP equivalent	0.81 kg	19.5 kg	5.8 mg/m^3
TCDD	0.23 mg	5.54 mg	1.65 ng/m^3
HCl	862.5 kg	20.7 mt	6.16 g/m^3
Particulates[*], carbon	42.8 kg	1.03 mt	305 mg/m^3
CO_2	31.3 mt[†]	752 mt	224 g/m^3
CO	16.8 kg	404 kg	120 mg/m^3
Inorganic particulates	170	4.08 mt	1.21 g/m^3

[*] Assumes 0.5 percent conversion to carbon.

[†] mt is metric ton, 1000 kg.

laden with waste, an environmental as well as a personnel concern. Both of these possibilities have been considered, and the low probability of either occurrence was acceptable when compared with other positive aspects of the proposed action. The vessel has been approved by the U.S. Coast Guard for operation from U.S. ports and will follow all applicable maritime regulations. The vessel has operated for some 10 years without encountering a situation in which the cargo had to be jettisoned.

Quantifying the impact of cargo jettisoning or ship sinking is not feasible because of the many assumptions necessary. Such an event in the harbor selected for ship loading could present very serious environmental impacts. However, proper contingency planning with emplacement of appropriate equipment at dockside will reduce the impacts of either event. Cargo jettisoning or ship sinking in the open ocean is not anticipated to present as serious an environmental threat as in a harbor. Any effects would be localized and not persistent. The location of the incineration sites off the continental shelf, the tremendous dilution afforded by the open ocean, the properties of the liquid silvex (i.e., rapid hydrolysis to the less toxic acids, settling because of specific gravity greater than unity, insolubility, and biodegradation), and the low biological productivity of the ocean areas involved would all tend to mitigate the impacts of a large scale release of the liquid silvex in the open ocean.

4.1.1.1 Impacts of Decanning Operations--

4.1.1.1.1 Impacts on air quality--Vapors escaping from the decanning facility will result in some atmospheric contamination. These effects can be minimized through the use of an enclosed facility maintaining proper ventilation, activated carbon filtration, or incineration of released vapors, and negative internal pressure (3). Since a site for this facility has not yet been chosen, criteria can be established in order to minimize potential impacts. The facility must be as far downwind as possible from any human receptors, sensitive vegetation, or other important ecosystems. Modeling was not performed because a site has not yet been selected.

Results of monitoring around the Herbicide Orange dedrumming facility in Gulfport, Mississippi showed that constituent levels in the air were low from an occupational point of view, but were still high enough to cause some damage to vegetation outside the facility (60). Levels of 2,4-D ranged from 7.76-141.15 ng/m^3 inside the facility to 0.09-5.76 ng/m^3 900 feet southwest of the facility and 0.13-3.88 ng/m^3 1500 feet east of the facility. Samples were also analyzed for TCDD, but it was not detected. These levels were well below the Threshold Limit Value (TLV) of 10,000 μg/m^3 for 2,4-D as established by the National Institute of Occupational Safety and Health (NIOSH) (66). This value is a time weighted average, based on 8 continuous hours of occupational exposure, for safe working conditions. Biomonitoring was accomplished by using young tomato plants known to be particularly sensitive to the herbicide formulation. These plants react within 24 hours to a herbicide concentration on the order of several parts per trillion. Plants within 500 feet downwind of the facility experienced moderate to severe damage, while plants within 1000 feet of the facility experienced slight to moderate damage. The conclusion to be drawn is that environmental impacts of decanning may be considered insignificant, provided there are no sensitive receptors within about 1500 feet downwind of the facility. Results of monitoring during dedrumming operations on Johnston Island were similar (64,57). In any event, all precautions should be taken to minimize toxic vapor release.

4.1.1.1.2 Impacts on water quality--Three routes are envisioned by which water may become contaminated with liquid silvex: small amounts of spilled or leaked material may find its way into ground or surface water, contaminated wastewater may be released to the environment, and escaped vapors may settle into local surface water.

In conformance with the proposed RCRA regulations (40 CFR 265) for hazardous waste storage facilities, the decanning facility will have dikes and floors which will be impervious to liquid silvex. Spills and rinse solvent used to clean up the spills will be collected and most likely will be incinerated. Solids used to absorb spills will be containerized and properly landfilled. The probability of any spilled material reaching the environment is very small.

Any water or kerosene used for cleaning machinery, protective gear, clothing, etc., will become contaminated with liquid silvex. This rinsate will be mixed with the liquid silvex and incinerated at sea as the liquid silvex is incinerated. Monitoring of wastewater resulting from the decanning operation will help identify any wastewater requiring such special treatment and disposal.

Trace quantities of liquid silvex vapors are expected to escape from the building housing the decanning equipment. Volatilized herbicide could settle into any surface water which may be in the vicinity of the building. As herbicide vapors are transported through the air, they will be reduced in concentration by dilution and degradative processes, such as photolysis and hydrolysis. Upon settling into a body of water the remaining herbicide will be further reduced by degradation processes, especially hydrolysis. Because of these degradation processes and because the amount of escaped herbicide vapors are expected to be small, it does not appear that this route will cause significant water contamination.

4.1.1.1.3 Impacts on soil, flora, and fauna--There are two routes by which decanning operations may result in liquid silvex components entering the soil: settling of the vaporized constituents onto the soil surface and spills of liquid silvex or contaminated rinsate onto areas not lined with impervious flooring. The amount of escaped vapors settling to the soil in the area near the decanning facility is expected to be very small. Because it is so small, no adverse impacts from this route of release are anticipated. Because of the precautions that will be taken to contain spills during decanning, the probability that any liquid silvex will enter the soil from uncontrolled spills is also very small. Nevertheless, a discussion of the fate of liquid silvex components in soil is given below.

Any soil which is known to contain spilled liquid silvex will be dug up. The herbicides will either be destroyed (e.g., by incineration of the soil) or isolated from the environment (e.g., by deposit in a secure landfill). Any liquid silvex components remaining in the soil may volatilize and move into the atmosphere, may leach and move down to the groundwater, or may decompose. Each of the components of liquid silvex would be expected to respond differently to each of these three processes.

Volatilization of some liquid silvex components would occur and tend to reduce their persistence in the soil complex. This is true for both the kerosene carrier and the phenoxy herbicides. The rate of volatilization and total amount of volatilization will depend on such factors as the soil moisture, soil pH, and ambient temperature. The amount of leaching will vary from soil to soil and depends primarily on the organic carbon content of the soils.

Goring, et al. (68) reviewed pesticide degradation in the soil and mentioned three main types of transformation which pesticides are reported to undergo in the soil: photochemical, chemical, and microbiological. Because radiant energy is strongly sorbed by soil, Goring et al. believed that very little photodecomposition would occur even at the soil surface. Thus, degradation of any liquid silvex which may find its way into the soil will be by chemical and microbiological processes.

The end products of pesticide transformation in soil are reported to be carbon dioxide, water, mineral salts, metabolites occurring in soil, and humic substances. Field studies on the degradation of 2,4-D and 2,4,5-T, including one study of 2,4,5-T mixed with diesel oil, were among the studies cited which led to this conclusion (60). Notably, no odor contaminant (phenols or catechols) were found in streams draining the treated watershed, indicating that chlorophenols are not decomposition products (69-71).

The persistence of the phenoxy herbicide components of liquid silvex varies. Because of its ability to undergo a number of transformation reactions, 2,4-D has a relatively short half-life in soil, <0.5 months (60). The half-life of 2,4,5-T in soil is reported to be 0.5 to 1.5 months (60). The half-life of silvex is expected to be very similar to that of 2,4,5-T. TCDD is reported to have a soil half-life of about one year (60).

In high enough doses liquid silvex can kill any vegetation with which it comes in contact. Lower doses may cause temporary defoliation, epinastic growth, or may have no effect. The effect from a given dose of phenoxy herbicide varies with species; broadleaf plants, for example, tend to be more sensitive than grasses. In general, phenoxy herbicides do not persist in plants. However, it has been reported that unmetabolized 2,4-D may bind to cell membranes in tomato plants and persist for two or three months (60).

During the Herbicide Orange incineration program, the area surrounding the decanning building was biomonitored with young tomato plants (60). At the Naval Construction Battalion Center (NCBC) in Gulfport, MS, moderate to severe plant damage was observed along the axis of prevailing winds at a distance of 500 feet from the building. Slight to moderate plant damage was observed in plants at 1000 feet from the building (60).

Although levels of vapor exposure were not quantified, the test results do help determine the size of the area that was exposed to at least low parts per trillion (ppt) herbicide vapor levels. Since many details about the silvex decanning operation are still not established, it is not yet possible to project the Gulfport results to the silvex decanning operation although there is not likely to be a big difference.

Animals may be exposed to liquid silvex components through ingestion of contaminated vegetation or soil. Phenoxy herbicides are readily absorbed in the gut of animals and are rapidly excreted in the urine. The rate of elimination from animals depends, to a great extent, on dosage (60). TCDD in the silvex formulations is the component of real concern since it is known to be teratogenic at microgram per kilogram dose levels. Bioconcentration of TCDD may occur in the liver and fat of animals ingesting contaminated vegetation or soil (60).

Assuming that the decanning operation occurs without incident (i.e., no uncontrolled spills), the only route which liquid silvex can be expected to enter the environment is via atmospheric transport of escaped vapors from the decanning building. The amount escaping is expected to be small. That which does escape will be diluted and, to some extent, degraded as it travels through the air. Upon settling in the soil or in local water bodies, the compounds will be further diminished in amount by rapid hydrolysis (within hours). Biological and nonbiological degradative processes would further reduce the level of any remaining residues in the soil or water. It is unlikely that toxic or even measurable levels of TCDD or phenoxy herbicide will accumulate in any animals or on any plants as a result of the decanning operation.

4.1.1.1.4 Impacts of container disposal--As described in section 2.2.1 and Reference 3, details of container handling and disposal have not yet been defined. The options are to incinerate the shredded metal cans without rinsing if there is a suitable on-site rotary kiln incinerator, or to rinse the shredded metal and glass containers by a method equivalent to the EPA triple rinse procedure (40 CFR 165.9). Glass shreds cannot be incinerated without melting. The cleaned, shredded containers are designated for landfilling; however, recycling should be considered in the interest of resource conservation. Either incineration under RCRA requirements (40 CFR 265) or a triple rinsing equivalent will produce scrap that is not hazardous for landfilling, and so no environmental impacts are expected.

4.1.1.1.5 Impacts of potential accidents and malfunctions--Decanning operations are not yet defined in detail; thus impacts of potential accidents and malfunctions cannot be described in detail. The facility used for decanning will meet all appropriate Federal, state, and local regulations; and all work will be performed according to detailed procedures.

Potential accidents and malfunctions during decanning and mitigation measures include the following:

- Spills within the decanning facility - The potential for significant spillage prior to or during decanning is low because of the small size of the herbicide containers and the limited holdup volume in the shredder. However, the decanning facility will have impervious floors with raised edges and blocked drains to prevent release of spilled material. Small leaks from process equipment may be contained in buckets while remedial measures are implemented. Large leaks may require temporary shutdown of the facility while repairs are performed. Emergency cleanup equipment (i.e., squeegees, pails, shovels and absorbent material) will be prominently situated to facilitate rapid cleanup of herbicide/rinse in the event of an accidental spill.

- Leakage from bulk silvex storage facilities - Because of the potential for significant leakage from bulk storage facilities, these facilities will be surrounded by a trench or diking to effect spill containment. Periodic visual monitoring will be performed to minimize the extent of leakage prior to initiation of facility repair efforts. Spilled material will be recycled to storage and/or recovered through the use of absorbent materials and decontamination procedures, consistent with the magnitude of the spill.
- Failure of the silvex vapor treatment units - While vapor incineration is the technically preferred option as compared to adsorption with activated carbon for control of vapors from the decanning facility, backup adsorption traps would be provided in case of incinerator shutdown. Where adsorption systems are employed (i.e., for bulk storage tank vents), backup adsorption units would be provided in case of vapor breakthrough. Spent adsorbent will be destroyed by incineration or landfilled.

Detailed operating, contingency, and health and safety plans to be written in support of decanning will include measures to minimize impacts of potential accidents or malfunctions.

4.1.1.2 Impacts of Transportation Operations--

4.1.1.2.1 Impacts on air quality--Air pollution impacts resulting from bulk transport of liquid silvex will be limited to escaped vapors under normal circumstances. These will originate from two sources: evaporation of spilled herbicide and release of ullage vapor during vessel filling. Small spills or leaks may occur regardless of the selected transportation mode, in which case some liquid will evaporate and enter the atmosphere. In the case of pipeline transport, such impacts should be minimized by frequent visual monitoring of seams, rivets and fittings for signs of leakage. Such impacts will be minimized for either rail car or tank truck transport since Federal regulations require careful monitoring of transport vehicles (DOT regulations, 49 CFR 174.8-174.10(b)1 and 123.31(b)1 for rail cars and tank trucks, respectively) (3). Emergency equipment will be on hand to clean up spills quickly. Also, the air displaced by filling an empty tank car or tank truck will be contaminated with vapor. All transport equipment vents will be fitted with activated charcoal filters to minimize this effect. It is impossible to be more specific at this time, since the mode of transportation from the decanning facility to dockside has not yet been defined. However, deleterious effects are expected to be insignificant in any case, provided no serious accidents occur.

4.1.1.2.2 Impacts on water quality--The modes of potential water contamination from silvex transportation to the ship are the same as those described for decanning. As in decanning, monitoring efforts along with spill containment and clean up procedures will minimize the amount of liquid silvex reaching the environment. The amount of herbicide released during normal transportation operations is expected to be very small.

4.1.1.2.3 Impacts on soil, flora, and fauna--The modes of potential land-based contamination were described in section 4.1.1.1. Silvex transportation to the ship will present the same modes. Thus, transportation to the ship is expected to result in very little release of herbicide. The fate and effect of herbicides in the environment were also discussed in section 4.1.1.1 on the impacts of the decanning operation on soil, flora, and fauna.

4.1.1.2.4 Impacts of potential accidents and malfunctions--Modes of transportation of the decanned silvex to the ship loading dock in order of descending preference are: pipeline, rail tank car, and tank truck. Pipeline transport provides more continuous operation, greatest control and security, and lowest potential for spills through accidents. If rail tank car or tank trucks are used, careful consideration will be given to hours of operation and control of other traffic unless the rail line or roadway is private.

The selected transportation vessel(s) will be carefully pressure tested for leaks prior to use. Catch basins will be placed under pipe connections, and absorbent material emplaced nearby. If tank car or truck transportation is employed, crossings will be guarded to minimize potential for collisions, and absorbent material and plastic sheeting stationed at each crossing for emergency cleanup, if required. Because of the low flash point of the formulations, special precautions will be taken against accidental ignition, e.g., prohibition against nearby flames or heat sources, and careful grounding of equipment used for handling the decanned silvex.

The detailed operating and contingency plans to be prepared will include preventative and mitigation measures to avoid any release of decanned silvex during transportation to the ship. Under these conditions, impacts of potential accidents and malfunctions will be minimized.

4.1.1.3 Impacts of Ship Loading Operations--

4.1.1.3.1 Impacts on air quality--Ship loading operations may impact air quality through uncontrollable release of herbicide vapor. This could occur through leaky pumps or couplings, as well as air displaced from the ship's cargo tanks. All shiploading activities will be continually monitored, making a large spill unlikely.

Experience shows very little impact from these operations. Monitoring performed during transfer of Herbicide Orange to the M/T Vulcanus showed very low levels of herbicide components in the air. While loading from rail tank cars near Gulfport, Mississippi, levels of 0.07-2.41 ng/m^3 of 2,4-D were detected (normal butyl ester form), and sensitive young tomato plants in the area showed no damage (60). While loading from tank trucks on Johnston Island, a peak value of 1.09 ng/m^3 was measured for 2,4-D (ester) and again, tomato plants were not damaged (60,67). These are so far below the accepted TLV value of 10,000 μg/m^3 for 2,4-D (66) as to be considered insignificant. TCDD was undetectable in both cases. Thus, environmental effects from shiploading are deemed insignificant, provided stringent spill prevention control is enforced.

4.1.1.3.2 Impacts on water quality--The modes of potential water contamination from ship loading operations are the same as those described for decanning and transportation operations. As in transportation, monitoring efforts along with spill containment and clean-up procedures will minimize the amount of liquid silvex reaching the environment. The amount of herbicide released during normal shiploading operations is expected to be very small.

4.1.1.3.3 Impacts on soil, flora, and fauna--The modes of potential land-based contamination were described in section 4.1.1.1. Shiploading will present the same modes. Normal shiploading operations are expected to result in very little release of herbicide. The fate and effect of herbicide in the environment were discussed in section 4.1.1.1 on the impacts of the decanning operation on soil, flora, and fauna. Potential impacts of a catastrophic spill resulting from a collision or other accident are greater than for minor spills because of the larger amount of herbicide involved.

4.1.1.3.4 Impacts of potential accidents and malfunctions--Of all activities associated with the proposed action, shiploading presents the greatest potential for adverse environmental impacts, primarily by spills. Cargo tank hatches are open during loading, samples of contents will be taken, and flex lines carrying cargo the ship are under pressure. An additional source of contamination is bilge water associated with the ship's pump room because there are typically small leaks from pump seals. Small but detectable amounts of cargo eventually end up in the bilge.

Potential accidents and malfunctions during shiploading and mitigation measures include the following:

- Leaks at the flex line connections - A large bucket is placed under the ship manifold connection to catch drips. Additionally, absorbent material will be kept in various locations on deck. This connection will be tested prior to pumping waste. If leaks larger than occasional drips occur, loading will be suspended until the problem can be fixed.
- Failure or leaks in the flex line - The flex line from the pump on shore to the ship will be thoroughly tested prior to use in shiploading operations, which will be suspended at any observance of a leak until the leak can be repaired.
- Overfilling of a tank - Tankers are equipped with automatic cargo tank level sensors which give visual and audible signals when a tank is filled. No problem would occur if these sensors failed during shiploading because the ship's loading procedure requires continuous observation of levels of cargo as tanks are being filled.
- Small spills from tank sampling - Top, middle, and bottom samples will be taken from each tank to check for immiscible layers. Small spills generally result from this. Absorbent material will be available on the ship for absorbing such spills. The area around each tank hatch will be covered with plastic sheet to catch small spills from sampling. The plastic

sheet will later be incinerated. Furthermore, the scuppers on the ship's deck are plugged with cement while in port to prevent any spilled waste from reaching the harbor water.

The contingency plan for the proposed disposal action will include detailed notification, and mitigation measures. Adherence to detailed procedures will minimize any potential environmental impacts of potential accidents and malfunctions during ship loading operations.

4.1.1.4 Impacts of Incineration in the Gulf Coast Incineration Site--

4.1.1.4.1 Impacts on air quality--The overall environmental effect of incineration in the Gulf of Mexico depends largely on the change in ambient conditions resulting from dispersion of the incineration products from the ship. These materials impact the atmosphere first, then enter the water and biological environments in turn. Burning liquid silvex in this manner is expected to produce four air pollutants of concern. These are 2,4-D; 2,4,5-TP; TCDD; and gaseous hydrochloric acid (HCl). Ambient concentrations of these materials were estimated by using a Gaussian plume dispersion model. The model and the inputs used for this analysis are discussed in detail in Appendix E.

Ambient air concentrations calculated at the sea surface under the centerline of the plume were studied in order to determine air quality impacts of incineration. The plume first contacts the water surfaces at 2500 meters, and a concentration peak occurs 16,000 meters downwind from the ship. Table 13 presents the highest estimated concentration at the sea surface for each of the four pollutants. It should be noted that these values are based on the highest possible mass emission output from the incineration ship, and on prevailing, i.e., statistically dominant, meteorological conditions for the Gulf Coast site. Whenever possible, accepted industry or occupational standards have also been included for comparison.

The pollutant concentrations are all far below the accepted standards. TLVs are commonly thought to fall an order of magnitude for every doubling of exposure time. The 16-hour averages are felt to be more applicable in this case, since incineration will occur for prolonged periods. Also, since 2,4,5-TP and 2,4-D are so similar, it would make more sense to sum their concentrations in order to evaluate toxicity. This gives 114.2 ng/m^3 of

TABLE 13. COMPARISON OF ESTIMATED MAXIMUM SEA-LEVEL CONCENTRATIONS IN THE GULF INCINERATION SITE TO STANDARD PERMISSIBLE LEVELS

Pollutant	Maximum Downwind Concentration at Sea-Surface	Maximum Permissible Level	Description of Permissible Standard
Silvex	38.00 ng/m^3	10 mg/m^3 (8 hour exposure) 1 mg/m^3 (16 hour exposure)	TLV, ACGIH* (72), OSHA (66)
2,4-D	76.16 ng/m^3	10 mg/m^3 (8 hour exposure) 1 mg/m^3 (16 hour exposure)	TLV, ACGIH, OSHA
TCDD	.011 pg/m^3	6 ng/m^3 (continuous exposure)	Maximum allowed on M/T Vulcanus (18)
HCl	40.35 μg/m^3	7 mg/m^3 (8 hour exposure) 0.7 mg/m^3 (16 hour exposure)	TLV, ACGIH, OSHA

* ACGIH - American Conference of Governmental Industrial Hygienists.

herbicide vapors, which is still far below the maximum permissible level of 1 mg/m^3 or 1,000,000 ng/m^3 (66) for a 16-hour exposure period.

The pollutant most closely approaching its maximum permissible level is HCl. There is an order of magnitude difference between the predicted sea-level maximum and the 16-hour exposure standard. Still, ecological effects should not be dismissed completely. Based on past experience with at-sea incineration, acid rain fallout can equal or exceed that produced by natural sources up to 10 miles downwind of the incinerator ship (4). Beyond 10 miles, the contribution of incineration is indistinguishable from natural sources. Natural sources include acidic sulphur, nitrogen, and chloride ions resulting from salt spray. These effects are transient and disappear shortly after incineration has stopped.

Some questions have been raised regarding possible destructive effects of organochlorine incineration emissions on the earths stratospheric ozone layer (4). It is true that chlorine of this type is destructive to the upper atmosphere's ability to filter ultraviolet rays, but the amounts in question here are clearly insignificant. It has been estimated that burning the entire world-wide production of organochlorine wastes would not inhibit this important function. Also, most chlorine is removed from the atmosphere at very low altitudes.

Estimated levels of TCDD appear sufficiently low to preclude any noticeable impact. However, TCDD is a very controversial substance, and its level of toxicity has not been conclusively established. The "safe" level given in Table 13 was derived from experimental results published by the U.S. Air Force (8,60). It is given in the absence of any more authoritative opinion. Also, the fate of TCDD during burning and in the ambient environment is not clearly understood. Some researchers have claimed that TCDD is actually generated in the combustion of trichlorophenoxy herbicides (73-75). However, none of these studies were performed at the high temperatures and long residence times in effect during at-sea incineration (14-16). Shih, et al. (76) recently summarized the literature on formation of chlorodibenzo-p-dioxins during combustion. Other investigators (64) think that TCDD will be effectively photodegraded in its volatilized form in the atmosphere. In any event, the maximum predicted TCDD concentration of 0.011 pg/m^3 is very close to current state-of-the-art limits of detection for this compound. The only possible environmental impact would be long term bioaccumulation of similar toxic substances through food chain transfer, which is not known to occur with TCDD.

In conclusion, the air quality impacts of burning liquid silvex in the Gulf Coast incineration area are minor. Ambient levels for 2,4-D; 2,4,5-TP; TCDD; and HCl at the sea surface will be far below the maximum permissible levels for humans. Ecological effects will be local, consisting of elevated acidic conditions within 10 miles downwind of the ship, and continuing only as long as incineration actually takes place. However, it must be kept in mind that airborne material will eventually deposit into the aquatic environment, where most of the biological effects will take place.

4.1.1.4.2 Impacts on water quality--The most important parameters affecting the water quality impact of at-sea incineration of silvex are completeness of combustion and destruction, feed rate of liquid silvex, and plume behavior. Combustion products (i.e., HCl and small amounts of unburned waste) can reach the ocean environment only via the plume. Models have been developed to describe the behavior of a typical plume from a source such as the M/T Vulcanus. The results of these models (section 4.1.1.4.1, Appendix E and References 8,52,77, and 78) along with the results of waste quality monitoring conducted during previous at-sea incineration projects (8,77,78) lead to the conclusion that there will be no significant water quality impacts from the at-sea incineration of silvex.

As has been mentioned earlier, 99.9 percent will be the minimum acceptable destruction efficiency. Actual destruction efficiencies are expected to exceed that. The destruction efficiencies for butyl esters of 2,4-D and 2,4,5-T during the incineration of Herbicide Orange exceeded 99.999 percent (35). The liquid silvex feed rate will be a maximum of 5.8 mt per hour per incinerator or about 11.6 mt per hour with both incinerators operating. Actual feed rates are expected to be lower.

Atmospheric conditions are an important factor in plume behavior. However, experience with at-sea incineration in the North Sea, the Gulf of Mexico, and the West Pacific revealed that wind speed (relative to the speed of the ship) and attitude of the ship with respect to wind direction also influences plume behavior and, therefore, water quality impacts (35).

From plume dynamics, one can draw conclusions about plume behavior at various ship attitudes. In an incineration site, it is often necessary for the ship to maneuver so as to remain within the prescribed boundaries or to drive in a given direction with respect to the wind in order to avoid plume impingement on the decks. Furthermore, drifting broadside to the wind is sometimes desirable when the weather is appropriate because it saves fuel and conserves the ship's position within the burn zone.

Three basic attitudes of the ship have been considered. These basic attitudes are arranged below in order of decreasing severity of impact on the water quality. The effects differ slightly depending on whether plume touchdown occurs close to or far from the ship. For plume touchdowns close to the ship, water quality impact severity is in the following decreasing order (15):

- Drifting broadside
- Driving directly into wind
- Moving at 90° to wind

For plume touchdown far from the ship, water quality impact severity assumes the following decreasing order:

- Driving directly into wind or drifting broadside (equal severity)
- Moving at 90° to wind

Although the best defined conditions are those of heading directly into the wind, there is enough evidence to validate the above generalizations (75).

Modeling performed in conjunction with this disposal program is described in Appendix E. Results of the modeling used to assess impacts on the marine air environment were presented above in section 4.1.1.4.1.

Previous studies have also modelled the water quality effects of at-sea incineration of chlorinated liquid wastes in an attempt to quantify worst-case water quality impacts (8,78). The three studies assumed a destruction efficiency of at least 99.9 percent. The chlorine content of the waste in the previous modeling studies was greater than that in liquid silvex. A

TRW study estimated that the area of plume contact with the ocean would be approximately 10^6 m^2 and assumed a mixing depth of 20 m (78). The Bayer Company estimated that in moderate winds the plume would spread over an area of at least 250,000 m^2. Their concentration calculations were based on dilution of emissions into only the top one meter of water (8). A study by the U.S. Air Force assumed a two meter mixing depth and calculated that the air emissions plume would cover a 6×10^6 m^2 area (8).

Using the same approach the U.S. Air Force adopted for their calculations (i.e., lateral plume dispersal of 490 m and mixing depth of 2 m), it is possible to project a quantified estimate of the water quality impact from the combustion of liquid silvex. If the ship travels at 10 knots or 18.5 km/hr, the plume width is 490 m, and the mixing depth is 2 m, then 24 hours of air emissions will be diluted with 4.4×10^{11} liters of sea water. Table 14 presents the average concentrations which will result when 100 percent of the emissions are dissolved into the volume of water calculated above.

The last column of Table 14 presents the concentrations which would occur if 100 percent of the same plume mixes into only 1.0 cm of water. This estimates the transient concentrations which would exist at the surface before mixing takes place. Surface dwelling species would be exposed to such concentrations for very short periods.

TABLE 14. ESTIMATED SEA WATER CONCENTRATIONS OF 2,4-D; 2,4,5-TP; HCl AND TCDD AT PLUME TOUCHDOWN

Compound	Emission Rate (kg/hr)	Concentration in Ocean - 2 m Mixing Depth	Concentration in Ocean - 1 cm Mixing Depth
HCl	862.5	47 μg/l	9.4 mg/l
2,4-D	1.63	89 ng/l	18 μg/l
2,4,5-TP	0.81	44 ng/l	9 μg/l
TCDD	0.231×10^{-6}	13 fg/l	2.5 pg/l

Mixing would soon reduce the concentrations to well below even those calculated for the 2 m mixing depth. This is partly because mixing depths at proposed sites are actually between 20 m and 200 m deep. Horizontal water movement from tides will result in still greater and more rapid dilution. Because of dilution, the ocean's buffering capacity, and the high background levels of chlorine, it is anticipated that the water quality impacts of incinerating liquid silvex at sea will be insignificant and very quickly reduced to undetectable levels.

Water sampling in the vicinity of plume touchdown during the combustion of organochlorine wastes aboard the M/T Vulcanus (16) found no significant difference in pH and copper (the most abundant heavy metal constituent of the waste) as compared to samples from control areas. Unburned organochlorine wastes were undetected in the water at the 0.5 ppb level (16). Sampling during the Bayer Company's burn detected temporary pH changes (maximum 0.5 pH units) within 50 m of the incinerator ship. Chlorinated wastes were not detected and were reported as being present in concentrations below 1.62 ppb (8).

It can be seen from the foregoing discussion that there are several factors capable of exerting considerable influence on the concentration of incinerator emissions in the plume, as well as on the extent of dilution of the emissions settling into the receiving water. Because of the number of such factors and their variability, the water quality impacts resulting from the incineration of liquid silvex are difficult to predict with much precision and may vary widely during the course of incinerating a shipload of waste. Modeling and monitoring of previous incineration projects indicate, however, that the water quality impacts will be temporary (e.g., pH effects) and very small (e.g., concentration of unburned waste).

In addition to the small amount of unburned herbicide which may settle into the ocean, small amounts of herbicide from on-deck spills may be washed into the ocean as well. Partially open tank hatches appeared to be the source of most of the minor spills which were observed during the incineration of Herbicide Orange (14). Sampling of the tank contents in port through these hatches caused several spills of about 10 to 20 ml each, and at one point a one liter sample bottle was spilled on deck.

Because settling air emissions of unburned liquid silvex and potential small spills resulting from normal shipboard operations may introduce trace quantities of liquid silvex into the ocean water, a discussion of the fate of herbicides in the ocean is appropriate. Little information on this topic is available. One study found that 90 percent of Herbicide Orange esters in seawater were hydrolyzed within 7 days into an alcohol and the herbicide acid (8). It appears that small amounts of herbicide discharged to the ocean will exist as a water soluble sodium salt (8). Photodecomposition appears to be the only removal mechanism for herbicides in the ocean environment. Crosby and Tutass (79) conducted an experimental study to compare the effects of sunlight on aqueous 2,4-D solutions and to identify any major decomposition products. They found that 2,4-D acid decomposed rapidly in water and ultraviolet light. Chlorodioxins, including TCDD, are rapidly degraded by ultraviolet radiation in the presence of hydrogen donors. Crosby (20) indicates that the natural organic film which covers most natural waters can serve as the hydrogen donor for the photochemical degradation of TCDD.

4.1.1.4.3 Impacts on marine flora and fauna--Since mixing takes time, the highest concentrations of any liquid silvex components entering the ocean environment will be at the water's surface. Thus, the small floating plants of the euphotic zone are the organisms most likely to be exposed to unburned or spilled herbicide. Species living below the surface may also be exposed, but because of dilution, the levels of exposure would be much lower.

Previous bioassay studies found that herbicides will cause moderate toxicity effects on marine algae at levels of 50-200 ppm. For example, Walsh (65) found that oxygen production in four species of marine algae was decreased by 50 percent when the algae were exposed for a period of 90 minutes to 50-60 ppm of the technical acid of 2,4-D (author's terminology), 100-200 ppm of the butoxy-ethanol ester of 2,4-D, and 50-150 ppm of the technical acid of 2,4,5-T. Walsh found similar results when measuring the effects of the same herbicides on the growth rates of the four algal species. Algal bioassays conducted by the U.S. Air Force found that Herbicide Orange inhibits growth at concentrations of 50-100 mg/l (8).

Aquatic toxicity studies indicate that other aquatic organisms will suffer adverse effects at lower concentrations. The TLm96* for 2,4-D is reported to be 1-10 ppm (60). Aquatic toxicity data for silvex and TCDD are not available.

Table 14 in section 4.1.1.4.2 showed that herbicide concentrations approaching 20 ppb may be achieved at the 1 cm mixing depth at water's surface. This is consistent with the results of biomonitoring tests conducted during March 1977 while organochlorine wastes were being incinerated at sea (16). During this test a device called a Biotal Ocean Monitor was used to expose fish (Fundulus Grandis) to the plume of the M/T Vulcanus.

The tests showed an elevation in the activity of the P-450 enzymes. These enzymes are located in the liver and are required for the metabolism of foreign chemicals introduced into an organism. The response noted (an increase in the P-450 activity) reflects the presence of a foreign material that has to be altered prior to excretion. When the exposed fish were returned to the laboratory and left in clean water for a few days, the enzyme activity returned to the level found in the control organisms (80).

Biological specimens of phytoplankton and zooplankton were also taken during a 1974 burn (35). Examination of chlorophyll-a levels (an indicator of phytoplankton activity), and adenosine triphosphate levels in the specimens showed no deleterious or subtle adverse impacts (35). This is consistent with the herbicide level predictions shown in Table 11 which indicate a safety factor for phytotoxic effects of almost two orders of magnitude, even before mixing takes place.

The experimenters concluded that the overall effects are localized and temporary (80) and do not represent a drawback to the use of at-sea incineration for organochlorine waste disposal. In attempting to generalize those results to the at-sea incineration of silvex, it must be recognized that the two wastes are very different. The concentration of toxic materials in the ocean environment from silvex incineration is expected to be lower than in previous burns, largely because of the fact that the liquid silvex waste is only about 30 percent herbicide and the TCDD content is about 20 ppb (Appendix A). Thus, the same destruction efficiencies experienced in previous burns would result in about 70 percent lower levels of unburned waste emissions of the liquid silvex burn.

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*TLm96 is defined as the concentration that will kill 50 percent of the exposed organisms within 96 hours.

Because of the very large dilution which any emissions settling into the sea will receive and because of the relatively low density of biota in the vicinity of the proposed incineration site, the probability of any lasting adverse impacts on the marine biota are believed to be extremely small.

4.1.1.4.4 Impacts of potential accidents and malfunctions--From an environmental viewpoint, incineration equipment failure events are critical when degraded performance or accidental release of hazardous materials occur. An accidental shutdown, without any polluting consequence, is a failure event that only results in an increased cost of operation. Primary concern here is for events with the potential for causing damage to human health or the environment. Such events may be caused by mechanical, material, or human error. Although it is virtually impossible to predict all possible accident events, a systematic analysis of incineration operations, and an evaluation of previous incidents during the combustion of organochlorine wastes at sea can help identify and mitigate the risks associated with the at-sea incineration of silvex.

Appendix E presents a detailed description of the M/T Vulcanus, an incinerator ship which may be used for the proposed disposal action. The waste handling and combustion operations are in-line functional processes, and with the combustion air blower system, form the three principal unit operations of the at-sea incineration system.

Potential malfunctions and accidents are listed in Table 15. Even though some records of downtimes and fail rates are available for some of the equipment used during incinerator operation on the Vulcanus (11,14-16), data are generally unavailable for an objective quantitative estimate of the probabilities of the potential accidents identified. The magnitude of the events, in terms of amount of uncontrolled release of waste, range from a few drops to as much as the entire load. A few drops are usually spilled when the

TABLE 15. INCINERATION PROCESS FAILURE MODE ANALYSIS

Waste Injection to Incinerator	- Ship motion causes spill from open tank hatch	Waste spill
	- Nozzle plugging (low flow detection)	Temporary shut-down
	- Atomization air loss on air blower failure	Failure to combust, toxic vapor discharge, liquid accumulation
	- Burner flame loss (flameout) due to fuel loss of pressure, loss of primary combustion, air, coking, or water slug in feed	Transient toxic vapor discharge prior to automatic shutdown on flame loss detection (or lower combustion temperature). (A water layer in the tank can be isolated by conductivity measurements and interlocked with the waste feed pump)
Combustion	- Improper fuel rate	Excess waste product in discharge
	- Improper air/fuel ratio	Inefficient combustion
	- Injection into a cool combustion zone on start-up	Inefficient combustion

steel tape used to measure the tank levels is removed from the tank; the entire load could conceivably be discharged to the sea under emergency conditions.

During incineration and rinsing operations the tank hatch covers have to be partially opened for pressure equalization. This can result in spills of herbicide or rinsate onto the deck. Most accidents identified result in the loss of liquid herbicide, but some of the combustion related accidents may release vapors of uncombusted or partially combusted herbicide. Smaller spills are generally confined to the ship and may pose a hazard to the ship's crew. Larger spills and combustion-related accidents could escape the confines of the ship and pose a threat to both the crew and the environment.

Another type of off-normal occurrence which may take place is the impingement of the incinerator plume on the ship and crew. This may occur following a burner flame loss or as a result of changing winds. As a result of a loss of flame in the incinerator, the velocity of emissions from the stack is reduced and the plume is cooler and denser than it is during normal operations. This changes the chemical composition and dispersion characteristics of the plume, which increases the chances for ship fumigation by the plume. Latent heat in the incinerator will vaporize any waste entering the combustion chamber following the flame loss, thus emissions may consist of partially combusted liquid silvex. Recorded incidents of ship fumigation during the at-sea incineration of Herbicide Orange lasted for short periods, all less than a minute (14). Herbicide residues left on the ship following these incidents were generally not detectable.

Another cause of plume impingements is stormy weather which causes the plume to eddy back onto all or part of the ship. The chemical components of this plume are those resulting from the normal operations of the incinerator and are described in section 4.1.1.4.1 on air quality impacts. Plume impingements of this type occurring during the incineration of Herbicide Orange were of short duration (10 to 30 seconds) and resulted in little personnel exposure (14).

Measures which are taken to reduce the chances that any of the incidents described above and in Table 14 will occur, have been included in the contingency plan and in detailed operating procedures prepared for the proposed action (3) and used by the ship's crew.

Additionally, there are numerous mechanical safeguards to prevent or mitigate release of waste to the environment. These are fully described in Appendix E for the M/T Vulcanus. Each burner is viewed by a flameout sensor. In the event of a flameout, waste flow to that burner is automatically shut off. Burner nozzle plugging or loss of combustion air are sensed automatically and result in waste flow shut off. The control panel in the incineration room is continually observed for any off normal events, and incineration can be rapidly terminated.

4.1.1.5 Impacts of Incineration in the North Atlantic Incineration Site--

4.1.1.5.1 Impacts on air quality--The air quality impacts of at-sea incineration in the North Atlantic area will be very similar to those experienced by burning in the Gulf Coast (see section 4.1.1.4.1). Somewhat different maximum concentrations will be observed because of different meteorological conditions. These are reflected in Table 16, which shows maximum downwind concentrations at the sea-surface. These maxima occur at a point of 14,000 meters from the ship. The plume touches the ocean surface about 3000 meters away from the ship.

As in the Gulf Coast case, all levels are comfortably below their associated permissible standards. Both 2,4-D and 2,4,5-TP components of the herbicide appear, but summing their concentrations still leaves a margin of four orders of magnitude between them and their TLV value for a 16-hour exposure period. Similarly, TCDD is five orders of magnitude below a value believed (3,18) to represent a safe continuous exposure level for humans. Gaseous HCl is one order of magnitude below its TLV for a 16-hour period, and is expected to create some local and transient acidic conditions downwind of the ship. Thus, the atmospheric impact of burning in the North Atlantic incineration site can be considered minor.

4.1.1.5.2 Water quality impacts--The parameters and processes identified and discussed in the previous section (4.1.1.4.2) on water quality impacts from incineration in the Gulf Coast site will also affect water quality impacts in the North Atlantic incineration site. Because environmental

TABLE 16. COMPARISON OF ESTIMATED MAXIMUM SEA-LEVEL CONCENTRATIONS IN THE NORTH ATLANTIC COAST AREA TO STANDARD PERMISSIBLE LEVELS

Pollutant	Maximum Downwind Concentration at Sea-Surface	Maximum Permissible Level	Description of Permissible Standard
Silvex	38.23 ng/m^3	10 mg/m^3 (8 hour exposure) 1 mg/m^3 (16 hour exposure)	TLV, ACGIH (69), OSHA (63)
2,4-D	76.63 ng/m^3	10 mg/m^3 (8 hour exposure) 1 mg/m^3 (16 hour exposure)	TLV, ACGIH, OSHA
TCDD	.011 pg/m^3	6 ng/m^3 (continuous exposure)	Maximum allowed on M/T Vulcanus (18)
HCl	40.60 μg/m^3	7 mg/m^3 (8 hour exposure) .7 mg/m^3 (16 hour exposure)	TLV, ACGIH, OSHA

factors, such as wind speed, wind direction, atmospheric stability, etc., can vary with the hour at either of the proposed incineration sites, there is no reason to expect that water quality impacts will be greater or lesser at one site or the other.

4.1.1.5.3 Impacts on marine flora and fauna--Potential impacts on marine flora and fauna in the North Atlantic incineration site would be as temporary and insignificant as the previously described impacts occurring at the Gulf Coast incineration site (section 4.1.1.4.3).

4.1.1.5.4 Impacts of potential accidents and malfunctions--Impacts of potential accidents and malfunctions during incineration at sea were described in section 4.1.1.4.4 and apply to incineration in the North Atlantic incineration site as well as in the Gulf Coast incineration site.

4.1.1.6 Impacts of Ship Cleaning Operations--

As discussed in this section, the potential for adverse environmental impacts from ship cleaning is very low. The bulk of the liquid silvex will have been incinerated. The concentration of waste components in the tank rinsing solution will be at trace levels. Thus, emissions of HCl and unburned waste components (esters of 2,4-D and 2,4,5-TP, and TCDD) will be orders of magnitude lower than the levels predicted for incinerating the liquid silvex. Potential impacts caused by potential accidents and malfunctions are also lower than during incineration operations.

4.1.1.6.1 Impacts on air quality--Minor air pollution emissions from ship cleaning will result from incineration of trace amounts of liquid silvex and diesel fuel or kerosene rinsate. These emissions will be of similar nature, but of much lower concentration than the actual silvex incineration emissions. In contrast to the incineration itself, these concentrations will be of insignificant, if not undetectable magnitudes. Therefore, no impact will result from this operation.

4.1.1.6.2 Impacts on water quality--The routes by which ship cleaning operations would potentially affect the environment are the same as those for incineration: potential minor spills during land-based sampling of tank contents rinsed into the sea and incinerator plume fumigation of the sea surface. However, during ship cleaning, the concentration of herbicide in the tank rinsate will be much lower than that in the liquid silvex waste. Therefore, the impacts on water quality from ship cleaning would be even smaller than the impacts from at-sea incineration; and the incineration impacts are expected to be insignificant.

4.1.1.6.3 Impacts on marine fauna and flora--The routes by which ship cleaning operations would potentially affect the environment are the same as those for incineration: potential minor spills during land-based sampling of tank contents rinsed into the sea and incinerator plume fumigation of the sea surface. However, during ship cleaning, the concentration of herbicide in the tank rinsate will be much lower than that in the liquid silvex waste. Therefore, the impact on marine flora and fauna from ship cleaning would be even smaller than the impacts from at-sea incineration; and the incineration impacts are expected to be temporary and insignificant.

4.1.1.6.4 Impacts of potential accidents and malfunctions--The potential for adverse environmental impacts resulting from accident or malfunctions during ship cleaning is low. The bulk of the liquid silvex will have been incinerated, and the concentration of liquid silvex in the tank rinsing solution will be very low. Potential failure modes described in section 4.1.1.4.5 are also applicable during ship cleaning. Potential adverse environmental impacts from ship cleaning operations are lower than those discussed in section 4.1.1.4.5 because the tank rinsate will be essentially pure kerosene.

4.1.2 Impacts of Land-Based Incineration

4.1.2.1 Impacts on Air Quality--

The air pollution caused by land-based incineration must be evaluated in light of the significant number of receptors it will impact. Unlike incineration at sea, this alternative may affect a substantial human population and whatever terrestrial ecosystems may be found in the area downwind of the incinerator stack. For this reason, wet scrubbing of the stack gas is necessary to bring the ambient levels of combustion products, particularly HCl, into a safe range.

Table 17 presents maximum ground level concentrations of the four constituents of concern to this study (2,4-D; 2,4,5-TP; TCDD; and HCl) with

TABLE 17. COMPARISON OF ESTIMATED MAXIMUM GROUND-LEVEL CONCENTRATIONS FOR THE LAND-BASED INCINERATION ALTERNATIVE TO STANDARD PERMISSIBLE LEVELS

Pollutant	Maximum Downwind Concentration at Surface	Maximum Permissible Level	Description of Permissible Standard
Silvex	113.5 ng/m^3	10 mg/m^3 (8 hour exposure) 1 mg/m^3 (16 hour exposure)	TLV, ACGIH (72), OSHA (66)
2,4-D	229.2 ng/m^3	10 mg/m^3 (8 hour exposure) 1 mg/m^3 (16 hour exposure)	TLV, ACGIH, OSHA
TCDD	.032 pg/m^3	6 ng/m^3 (continuous exposure)	Maximum allowed on M/T Vulcanus (18)
HCl	.60 μg/m^3	7 mg/m^3 (8 hour exposure) .7 mg/m^3 (16 hour exposure)	TLV, ACGIH, OSHA

appropriate TLV or other comparison values. Summing the concentrations of 2,4-D and 2,4,5-TP gives a total concentration of 342.7 ng/m^3 of herbicide ester. This is more than three orders of magnitude lower than the TLV (66, 72) standard of 1 mg/m^3 (1,000,000 ng/m^3) for a 16-hour period. TCDD is five orders of magnitude below its calculated (18) safe level for a 16-hour period. Therefore, it is safe to conclude that these air pollutants, at the ambient levels produced by land-based incineration of silvex, present no human health problems. However, it is known that young tomato plants, which are particularly sensitive to the toxic effects of silvex herbicide, are affected by levels of herbicide in the range of 10 ng/m^3 (10 ppt) (60). Ambient silvex levels of 300 ng/m^3 would damage vegetation as sensitive as tomato plants. It must be pointed out that these values assume no removal by the scrubber (only HCl removal has been accounted for in this analysis) since removal efficiencies for unburned herbicide components are unknown, and a worst case effect was desired. However, until shown otherwise, it must be concluded that some ill effects could be felt by sensitive vegetation growing downwind of the incinerator.

According to the dispersion analysis (Appendix E) peak concentrations occur about 2000 meters downwind of the incinerator stack. The plume reaches ground level rather quickly, with significant concentrations (relative to the peak) occurring well before 1000 meters. Residual herbicide levels drop to 10 ng/m^3 at around 60,000 meters.

Scrubber action will remove most of the HCl and particulate matter from the incinerator stack gas. Therefore, impacts from these materials will not be discussed further. It is possible, however, that a secondary air impact could be produced, depending on the sludge disposal method.

In conclusion, emissions from land-based incineration of silvex are low, as compared to TLV and other values. This indicates a lack of significant impact as far as direct human effects are concerned, but levels may be high enough to cause some vegetative damage. It is admitted that the numbers produced by this analysis are extremely conservative, but more study is required before a conclusion of insignificant impact could be made.

4.1.2.2 Impacts on Water Quality--

The activity associated with land-based incineration of silvex which is most likely to adversely affect water quality is the disposal of scrubber wastewater. Another route of water contamination is the deposition of air emissions into nearby water bodies. Characteristics of the scrubber waste which have the greatest potential for affecting the environment include chlorine residues, total dissolved solids, suspended solids, heat, and hydrocarbons.

4.1.2.2.1 Scrubber water characterization--The use of either a recirculating or single-pass scrubber is an important factor in determining the characteristics of the scrubber water. Blowdown from recirculating systems generally occurs when the salinity reaches about 3 percent (i.e., total dissolved solids (TDS) of 30,000 mg/l) (Ref. 78, p. 32). The blowdown rate is variable, depending on the amount of chlorine in the liquid incinerated and on the liquid feed rate.

The characteristics of single-pass scrubber effluents are highly variable, depending on the chlorine content of the liquid incinerated, the liquid feed rates, the scrubber solution feed rates and the efficiency of the scrubber. Because single-pass systems have so many variables, it is not possible to calculate a normal or average TDS concentration. However, it is possible to estimate the magnitude of TDS concentration. This has been done by using two sets of data shown in Tables 18 and 19. The data were picked because their operating parameters produced two extremes in scrubber water quality, as shown in Table 18. Details of the calculations are given in Appendix F. Generally, scrubber wastewaters will contain TDS concentrations less than 40,000 milligrams per liter.

Tests conducted by the U.S. Air Force and the Marquardt Company on the combustion of Herbicide Orange in a commercial incinerator indicate that a small amount of organic compounds will be found in the scrubber water (8). Four test burns using slot-type fuel injection nozzles resulted in no detectable herbicide feed compounds in the spent scrubber water. One of four test runs using a central poppet type fuel nozzle did result in a positive assay for TCDD (0.25 μg/l). This finding was attributed to the characteristics of poppet nozzle fuel injection (8).

TABLE 18. SCRUBBER WATER AND WASTE PARAMETERS FOR TWO LAND-BASED LIQUID INJECTION INCINERATORS

Parameter	Waste Incinerated: Hexachlorocyclopentadiene*	Waste Incinerated: Nitrochlorobenzene†
Fresh Scrubber Water Feed Rate (liters/min)	60	3200
Caustic Solution Feed Rate (liters/min)	23.8	8.5
Type of Solution Used	12% NaOH	32% $Ca(OH)_2$
Liquid Waste Feed Rate (kilograms/hr)	52.8	1893
Elemental Chlorine Content of the Waste	77%	10%

*Source: Reference 81.

†Source: References 82,83.

TABLE 19. RESULTS OF SCRUBBER WATER QUALITY CALCULATIONS

Pollutant	Waste Incinerated: Hexachlorocyclopentadiene	Waste Incinerated: Nitrochlorobenzene
Chlorides (milligrams/liter)	10,700	1,310
Calcium (milligrams/liter)	--	530
Sodium (milligrams/liter)	24,800	--
Total Dissolved Solids (milligrams/liter)	35,500	1,840

Some of the combustion gas hydrocarbons appeared to dissolve into the scrubber water as well. Some pyrolyzates (e.g., nonchlorinated aliphatics, aromatics, and biphenyls) in the combustion gases reacted with the oxidants in the combustion gas (HCl, Cl_2, and monatomic chlorine) and the caustic to produce hydrolyzates (e.g., monochlorobenzene and dichlorobenzene) (8). The average concentration of these pyrolyzates and hydrolyzates expressed as carbon in the spent scrubber water averaged 0.60 mg/l for the first three burns and 0.02 mg/l for the last five burns. Comparison of both water and gas hydrocarbon analyses showed that improved combustion efficiency in the last five burns significantly reduced the hydrocarbons delivered into and collected by the scrubber (8).

4.1.2.2.2 Handling of scrubber wastewater--The risks associated with scrubber water are not only a function of the degree of hazard of the waste stream but also depend on the method of treatment and disposal. A typical treatment and disposal scheme is described below. Actual treatment and disposal would depend on a number of local factors such as the evapotranspiration rate, available disposal methods, local regulations, etc. Another important factor would be a determination of whether the scrubber sludges meet EPA criteria (40 CFR 265) as hazardous wastes or not.

Scrubbers used at facilities which incinerate organochlorine compounds are designed to remove HCl and particulates that may be generated as combustion products. Therefore, treatment normally includes clarification (to remove particulates), neutralization (to take care of any residual acid or base that may still be present), and dilution (to help control TDS levels). Particulates which are insoluble in the scrubber fluid become suspended solids in the scrubber wastewater. If the particulates dissolve in the scrubber fluid, they contribute to the wastewater's TDS level. Suspended solids in scrubber wastewater generally present few, if any, problems because their concentrations are usually less than 5 mg/liter. Suspended solids are usually removed by on-site settling ponds.

Wastewater with either high or low pH levels must be neutralized prior to final discharge (to a municipal sewer, or receiving stream). This is usually accomplished by adding either acid or base.

The high concentration of total dissolved solids (from NaCl, $CaCl_2$, and in some cases the excess NaOH not expended in neutralizing the HCl) must be reduced. This is usually accomplished by piping scrubber effluents to in-plant treatment systems or by diluting with other plant process streams and storing in a holding pond or lagoon.

In geographical locations with high evapotranspiration rates, solar evaporation could be used as a method for disposing of scrubber wastewater. For such a method to be considered environmentally acceptable, the scrubber wastewater would have to be devoid of potentially hazardous volatile materials. The ponds used for evaporation would have to be periodically drained and the accumulated sludge removed.

Information contained in a draft position paper concerning RCRA indicates that EPA regulatory officials may consider residue resulting from the incineration of hazardous wastes as also being hazardous (84). Moreover, RCRA regulations (40 CFR 265) state that one of the general guidelines of RCRA is that waste disposal activities should be performed in a manner which precludes discharges to the environment. If these concepts and rules are implemented within the regulatory controls required by RCRA, significant restrictions will be imposed on the manner in which scrubber wastewater is handled. Three stipulations from the draft RCRA regulations indicate that such restrictions may indeed be imposed. These stipulations are: 1) scrubber wastewater must be impounded prior to discharge or disposal, 2) releases must occur through a point source, and 3) discharge is to take place in a manner which allows for composite sampling for compliance testing. Thus, scrubber wastewater discharged to municipal sewers may be routinely sampled to insure that it doesn't contain unacceptable levels of unburned organochlorine wastes or toxic elements. Similarly, the sludges or other sediments collected from settling ponds, evaporation ponds, or other types of lagoons may also contain unburned wastes or toxic trace elements (abstracted from the combustion gases as particulates, or formed as precipitates following chemical reactions occurring in the pond). These sludges will have to be disposed of in a manner consistent with the objectives of RCRA.

4.1.2.3 Impacts on Soil Flora and Fauna--

The eight previously mentioned test burns conducted on Herbicide Orange were accompanied by biomonitoring efforts in addition to the chemical analyses performed on the spent scrubber water and atmospheric emissions. Atmospheric biomonitoring included observations made on local flora and test plants in the vicinity of the incinerator. Biomonitoring of the spent scrubber water consisted of bioassays performed on two different species.

The test plants used in the atmospheric biomonitoring tests were 160 young tomato plants. Tomato plants are known to be especially sensitive to chlorophenoxy herbicides. No herbicide or other chemical damage to either the test plants or local flora in areas downwind from the incinerator was observed (60).

Biomonitoring of the eight spent scrubber waters consisted of bioassays performed on a representative sample of each test burn. Each sample was composed of numerous portions of spent scrubber water collected throughout the entire length of a test burn. Test animals used in the bioassays were 3-spine sticklebacks (Gasterosteus aculeatus) and brine shrimp (Artemia salina). No unexpected toxic effects were observed. The chlorine produced by incinerating the herbicide (a chlorinated hydrocarbon) was collected as free, available chlorine in the scrubber waters. As expected, free chlorine in the spent scrubber waters produced lethal effects on sticklebacks at 20-35 times the toxicity seen in scrubber waters in which the chlorine had been removed. The bioassays with the spent scrubber waters were compared to similar toxicity studies with artifical spent scrubber water. The "artifical" spent scrubber water was used to establish the toxicity to be expected when aquatic organisms are exposed to such a solution. Also, toxicity studies were performed to determine the effects of osmotic gradients on the test animals. The toxicities seen with the spent scrubber waters in which free chlorine had been removed were not significantly different from the toxicity found with artifical spent scrubber water. Osmotic toxicity studies indicated that unavoidable osmotic effects contributed largely to the toxic effects seen in the spent scrubber waters (60).

4.1.2.4 Impacts of Potential Impacts and Malfunctions--

Although a candidate facility for the land-based incineration alternative has not been selected, the facility operated by Rollins Environmental Services, Inc., located in Deer Park, Texas, has been used as a model representative of land-based incinerators. This is a centralized facility extensively used for incineration of organochlorine wastes. The Rollins facility is described in section 2.3.

Failures during the land-based incineration alternatives have the potential of causing adverse environmental impacts only when they result in degraded performance or release of the liquid silvex. It is well knwon that industrial equipment malfunctions are only partially caused by mechanical or material failure. The other chief contributor to faulty operations is related to human failures: simple errors, ignorance, negligence, or deliberate violation of procedures and policies.

Table 20 presents a listing of some possible malfunctions at a land-based incinerator. The waste storage tank and transfer area represent the greatest potential for adverse environmental impacts in the event of an accident or malfunction. Interim RCRA regulations (45 FR 33221) require paving and diking in these areas. Absorbent material will be available at strategic locations for cleanup of small spills or leaks.

Potentially adverse but lesser environmental impacts can arise from malfunctions in incinerator operations: burner flame out; improper fuel, air, and waste feed rates; improper scrubber operation; or inadequate wastewater treatment. The Rollins facility is equipped with automatic controls to shut down operations when off normal conditions occur.

When a candidate facility for the land-based incineration alternative is selected, detailed operating and contingency plans will be prepared. These plans will address potential malfunctions and corrective measures in order to minimize environmental and public risk.

4.1.3 Summary: Effects on Public Health and Safety

The proposed project poses a potential hazard to the workers involved in the project and to the larger public. The probable impacts on these two groups from both land-based and at-sea phases of the project are discussed below.

TABLE 20. POTENTIAL OPERATIONAL MALFUNCTIONS AT A LAND-BASED INCINERATION FACILITY

Operation	Possible Malfunction	Consequence
Tank Filling	1. Overfill on level interlock failure	Waste spill
	2. Leakage due to pump seal, valve packing material corrosion, etc.	Small waste spill
	3. Inclusion of unauthorized waste by subversion of quality control procedures	Possible incineration difficulties
Waste Transfer through Pump and Filter	1. Leakage due to pump seal, material corrosion, etc.	Small waste spill
	2. Filter plugging	None if filters switched on high pump discharge pressure measurement
Waste Injection to Incinerator	1. Nozzle plugging (low flow detection)	Temporary shut-down
	2. Atomization air loss on air blower failure	Failure to combust, toxic vapor discharge, liquid accumulation
Incineration	1. Burner flame loss (flame-out) due to loss of fuel pressure, loss of primary combustion air, coking, or water slug in feed	Transient toxic vapor discharge prior to automatic shutdown on flame loss detection (or low combustion temperature. A water layer in the tank can be isolated by conductivity measurement interlock to the waste feed pump)
	2. Improper fuel rate	Excess waste product in discharge
	3. Improper air/fuel ratio	Inefficient combustion
	4. Injection into a cool combustion zone on startup	Inefficient combustion
Stack Gas Scrubbing	1. Scrubbing solution circulating pump fails	High HCl concentration in stack gases
	2. Weak scrubbing solution	Not much change, even water scrubbing is very effective for HCl removal
	3. Pump, valve, or tank leaks	Scrubbing solution spill (no consequence if water is used for scrubbing)
Wastewater Treatment	1. Chemical addition pump fails	Low pH discharge
	2. Pump, valve, or tank leaks	Small wastewater spill

The principal hazard from the land-based operations would be an occupational one, the inhalation of liquid silvex vapors. As discussed in previous sections, the highest levels of exposure will be in the structure housing the decanning equipment. During the dedrumming of Herbicide Orange at the Gulfport, MS, facility, vapor concentrations of the n-butyl ester of 2,4,5-T ranged from 3.01 to 79.62 $\mu g/m^3$, while 2,4-D n-butyl ester vapor levels ranged from 7.76 to 141.15 $\mu g/m^3$ (60). These levels were well below the 8-hr TLV of 10,000 $\mu g/m^3$.

As has been mentioned earlier in this report, the herbicide vapor concentrations from decanning the silvex formulations are expected to be lower than those encountered during the Herbicide Orange program because the 2,4-D and 2,4,5-TP esters are less volatile than the 2,4-D and 2,4,5-T esters in the Herbicide Orange. Additionally, vapor control methods and safety requirements described in Reference 3 are expected to reduce this potential hazard to negligible levels.

Inhalation of TCDD is another potential health hazard. An ambient TCDD concentration of 0.06 $\mu g/m^3$ was proposed as a "no effect" level for humans in the Safety Plan for Incineration of Herbicide Orange On Board the M/T Vulcanus (18). This was based on laboratory studies which found that TCDD dose levels of 0.03 to 0.1 $\mu g/kg/day$ were no-effect levels of embryotoxicity and chick edema. It was then assumed that an average person weighs 60 kg and inhales 30 m^3 of air in a 24-hour day. Thus, a 60 kg person could inhale as much as 60 kg x 0.03 $\mu g/kg$ = 1.8 μg in 24 hours and still be below the no-effect dose level. This corresponds to the ambient concentration of 1.8/30 = 0.06 $\mu g/m^3$.

During Herbicide Orange dedrumming operations on Johnston Island, ambient TCDD levels were below the minimum detectable limit (MDL) of 6.6 to 20.3 ng/m^3. Ambient TCDD levels during the Gulfport, MS, decanning operation were below the minimum detectable limit (MDL) of 24.4 to 35.9 ng/m^3 (60,67). Ambient TCDD levels during liquid silvex decanning operations are also expected to be lower than those encountered in the Herbicide Orange project because using a shredder for decanning involves a considerably smaller work area which promotes much better vapor control.

The ambient levels of herbicide and TCDD vapors during Herbicide Orange decanning were well below TLV (60,67) and calculated no-effect levels (18). The herbicide and TCDD vapor levels encountered during the decanning of silvex are expected to be lower than those encountered in the Herbicide Orange project. It is expected that there will be no adverse health effects due to worker inhalation of herbicide or TCDD vapors from the land-based operations associated with silvex disposal project.

Decanning of Herbicide Orange on Johnston Island resulted in a few industrial accidents such as slipping on the floor, nail puncture wound, finger pinched between drum, etc. The only accident type involving the herbicide itself was the spraying of herbicide in workmen's eyes. Three such incidents were reported (67). Since a different method of decanning and rinsing the empty containers will be used in the proposed silvex disposal action, splashing of herbicide in the eyes is not anticipated to be a problem. The potential for other industrial accidents will have to be further assessed when the decanning operation is further defined.

The principal occupational hazards to personnel on board the M/T Vulcanus are exposure to herbicide vapors in some of the working areas and exposure to the incinerator plume emissions under conditions which cause the plume to fumigate the ship. During previous at-sea incinerations of Herbicide Orange, workspace air was monitored in the dining room, combustion room, pump room, and portable laboratory. Concentrations in the four areas monitored were low, ranging from 0.06 to 174 $\mu g/m^3$ (14). These values were well below the 8-hour TLVs of 10,000 $\mu g/m^3$. Exposures to vapors of 2,4-D and 2,4,5-TP esters during the proposed action are expected to be equally small, so that no adverse health impacts are expected.

Plume impingement or eddying of the plume onto the ship could expose the ship's crew to vapors of unburned herbicide, TCDD, HCl, and other combustion products. There were several occasions of plume impingements documented on previous at-sea incinerations (14). The levels of exposure were not documented but are believed to have been less than 8-hr TLV values. The durations of these incidents were short, ranging from 5 to 30 seconds. Medical examination of the crews following these incinerations revealed no health effects (14).

Experience gained during previous at-sea incinerations showed that precautions could be taken to reduce the chances of plume contact with the ship. These precautions have been incorporated into the Operations Plan (3) for the proposed action. It appears, then, that neither escape of herbicide vapors nor plume impingement pose significant occupational health hazards.

The public health impacts of the silvex disposal project are expected to be insignificant as well. Public exposure to escaped vapors from the land-based operations will depend on the final configuration of the land-based systems. However, public exposures will certainly be lower than the occupational exposures since vapor levels inside the decanning structure will be much higher than those outside the structure. Since occupational exposure levels are expected to be safe, public exposure levels are also expected to be safe. Discussions in Section 4 indicated that there would be no significant contamination of soil or water from the land-based operations either. Therefore, public exposure to liquid silvex via water or food contamination is not likely.

The public health risk from at-sea operations is also expected to be insignificant. This is because of the amount of potentially hazardous materials released at sea via minor spill and incinerator emissions is expected to be very small. The fact that both the Gulf Coast and Atlantic incineration sites are far from habitated coast lines, well away from normal shipping lanes, and are not currently used for either commercial or sport fishing further reduces the chances of any public health effect.

4.1.4 Summary: Effects on the Ecosystem

The proposed liquid silvex disposal action could affect the terrestrial ecosystem in which the land-based operations take place, and it could affect the marine ecosystem in which the at-sea operations take place. The likely routes by which liquid silvex could reach the terrestrial ecosystem are escaped vapors, particularly from the decanning step, and minor spills onto the soil. The herbicide vapors could cause epinastic growth in local vegetation within the immediate vicinity of the decanning structure. The environmental fate of the herbicide is discussed earlier in Section 4, and it is expected that the amount of liquid silvex likely to enter the terrestrial ecosystem is very small. Biological and nonbiological degradative processes would further reduce the levels of any escaped liquid silvex. It is therefore expected that the land-based phases of the project will not result in the accumulation of toxic levels of either herbicide or TCDD.

The marine ecosystem could be contaminated via touchdown of the incinerator plume on the ocean surface and by minor shipboard spills which are washed overboard. The surface dwelling organisms are the most likely ones to be exposed to toxic levels of contaminants, as is discussed in section 4.1.1.4. Previous studies, however, indicate that the effects on the organisms are temporary. Mixing of the surface waters quickly reduces the contaminant concentrations to very low levels. Because of this and the fact that the density of biota in the proposed incineration sites is so low, incineration of liquid silvex at sea is not expected to contribute to the bioaccumulation of herbicide or TCDD in the marine ecosystem. Any effects which may occur are expected to be transient, negligible, and highly localized.

4.2 ADVERSE ENVIRONMENTAL IMPACTS WHICH CANNOT BE AVOIDED

Previous herbicide decanning operations and at-sea waste incineration projects were monitored for environmental impacts. The extent of the emissions and the events leading to the emissions were documented (11-16,60). An examination of the reports which followed the previous projects suggests some procedure modifications which could reduce the environmental impacts associated with incinerating hazardous wastes at sea. These modifications have been incorporated into the Operations Plan for silvex disposal (3). As a result, incinerating liquid silvex at sea would involve only insignificant adverse environmental impacts.

Analysis of the proposed project reveals that the likely direct impacts would be very small and transient. This is discussed more fully earlier in section 4. Herbicide vapor emissions from the decanning operation are expected to be much lower than those from previous decanning operations; however, it is not expected that they will be eliminated completely. The low levels of escaped herbicide vapors will be further reduced by chemical and microbiological decomposition. No significant effect on flora or fauna is expected from these vapors. The incineration of liquid silvex and rinsate will cause air emissions on water quality, marine flora, and marine fauna are expected to be insignificant and transient.

Indirect impacts from the proposed project would be attributed to the project's consumption of energy and materials. For example, generating electricity used for decanning will cause air emissions as will sailing the incinerator ship. Since the energy and material consumption from this project would be relatively small, the indirect environmental impacts would be minor.

4.3 RELATIONSHIP BETWEEN SHORT TERM USES OF MAN'S ENVIRONMENT AND MAINTENANCE AND ENHANCEMENT OF LONG TERM PRODUCTIVITY

It is expected that there will be no long-lasting effects from the normal operations associated with disposing of liquid silvex by incineration at sea. Because the amount of herbicide released from decanning will be so small and because of the soil's tendency to adsorb and degrade any settled vapors, the project is not expected to contribute to bioaccumulation of herbicide or TCDD on land, if such accumulation does occur. Similarly, because of the incinerator's high destruction efficiency and the proposed incineration sites sparsely populated ecosystem, the project is not expected to contribute to the bioaccumulation of herbicide or TCDD in the marine ecosystem. The destruction of liquid silvex by incineration would eliminate the short- and long-term risks associated with the continued storage of liquid silvex.

4.4 IRREVERSIBLE OR IRRETRIEVABLE COMMITMENTS OF RESOURCES WHICH WOULD BE INVOLVED IN THE PROPOSED ACTION IF IMPLEMENTED

The amount of resource consumption that would result from the proposed project cannot be determined with much precision at this time. It would largely depend on the extent to which the equipment and structures used for the land-based operations are reused or recycled. A temporary structure may be used for the decanning operation and concrete or plastic lining may be required for other steps of the land-based activities. Disposable coveralls may be used to avoid contaminating clothes washing water. Kerosene will be used to clean the land-based equipment and to rinse the incinerator ship's storage tanks. Perhaps as much as 1000 m^3 will be required. It does not appear that a very large material resource consumption would be required by the proposed action.

The amount of energy consumed by the project would not be very large either. The land-based activities will use some energy for the operation of the shredder, blowers, pumps, etc. A larger but still relatively small amount will be used by the incinerator ship for ship movement and onboard incineration activities (e.g., pre-heating the incinerator and pumping of waste), and ship cleaning.

5. LIST OF PREPARERS

Table 21 lists the qualifications and professional disciplines of those persons who were primarily responsible for preparing this EA, along with the portion of the document attributable to each. EPA evaluation of the scope and contents of this EA was the responsibility of Mr. Ray Krueger, of the Benefits and Field Studies Division of EPA's Office of Pesticide Programs. Mr. David C. Sanchez, Office of Research and Development, Industrial Environmental Research Laboratory, was the Project Officer.

TABLE 21. LIST OF PREPARERS

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Professional Discipline(s)	B.S. Chemistry Ph.D. Analytical/ Chemistry	B.S. and M.S. Mechanical Engineering	B.S. Environmental Science	B.S. Chemical Engineering	B.A. Biology M.P.H. Environmental Health Management
Years Experience	12	24	1	3	1
Expertise	(a) Manager of Laboratory Operations Work Package, "Emissions Assessment of Conventional Stationary Combustion Sources," EPA Contract No. 68-02-2197 (b) Manager and Team Leader of Monitoring Activities, "At-Sea Incineration: Sampling, Analysis, and Environmental Assessment," EPA Contract No. 68-02-2660 (c) Manager of Laboratory Operations Work Package and team leader for two burns, "At-Sea Incineration of Herbicide Orange," EPA Contract No. 68-01-2966 (d) Manager of Sampling and Analysis for one facility test, "Destroying Chemical Wastes in Commercial Scale Incinerators," EPA Contract No. 68-01-2966	(a) Manager of Instrumentation Evaluation, "At-Sea Incineration: Sampling Analysis, and Environmental Assessment," EPA Contract No. 68-02-2660 (b) Task Manager, "At-Sea Incineration of Herbicide Orange," EPA Contract No. 68-02-2966 (c) Program Manager, "Destroying Chemical Wastes in Commercial Scale Incinerators," EPA Contract No. 68-01-2966 (d) Task Manager, "Development of a Protocol for Evaluation of the Thermal Destruction of PCBs," EPA Contract No. 68-02-3174	(a) Modeling and Impact Analysis, "Offshore Incineration Platform Feasibility Study," EPA Contract No. 68-02-2613 (b) Academic Specialization in Environmental Engineering	(a) Staff Environmental Analyst, hazardous waste management studies (b) Staff Environmental Analyst, "Conventional Combustion Environmental Assessment," EPA Contract No. 68-02-3138 (c) System evaluation "Development of a Protocol for the Evaluation of the Thermal Destruction of PCBs," EPA Contract No. 68-02-3174 (d) Specialization in environmental law	(a) Staff Environmental Analyst hazardous waste management studies encompassing several industries including pesticide manufacturing (b) Doctoral candidate in Environmental Science and Engineering
Role in EIS Preparation	(a) Technical Task Manager (b) Outline, Summary, Section 1, Introductions to Sections 2-4, Impacts of Potential Accidents and Malfunctions (c) Technical Editor	(a) Alternatives including Proposed Action (Sections 2.1,2.4 through 2.10) (b) Affected Environment (lead-ins to Sections 3.1.1, 3.1.2 3.1.3, 3.1.4, 3.1.5 3.1.6, and 3.2)	(a) Air Quality Impact Assessments (Section 4) (b) Meteorological conditions (Section 3) (c) Plume Dispersion Modeling (Appendix E)	(a) Descriptions of At-Sea and Land-Based incineration (Sections 2.2 and 2.3) (b) Other activities in the vicinity of the site (Section 3) (c) Transportation Requirements (Appendix F)	(a) Water quality and Soil/flora/ fauna impact Analysis (Sections 2 and 4) (b) Biological and hydrological conditions in the affected environment (Section 3) (c) Summaries of Effects on Public Health and Safety and on the Ecosystem (Sections 4.1.3 and 4.1.4)

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APPENDIX A

CHARACTERIZATION OF LIQUID SILVEX

A. CHARACTERIZATION OF LIQUID SILVEX

Permits for at-sea incineration of chemical wastes are issued under the Marine Protection, Research, and Sanctuaries Act (MPRSA). On requirement of MPRSA for issuing permits is a characterization, both chemical and physical, of the material to be burned. This section describes the physical and chemical characterization of liquid silvex formulations and defines the sampling and analysis scheme designed to validate the TCDD content of the silvex formulations.

A.1 PHYSICAL AND CHEMICAL CHARACTERIZATION

EPA funded a Contract (No. 68-02-2613, Task No. 33) to determine chemical and physical characterization of several silvex formulations, and the results of this effort were reported in Reference 1. Table A-1 (1) presents product specifications taken from container labels. (Active ingredients are specified to be present in quantities not less than the values given on the labels.) Table A-2 (1) presents the results of physical and chemical characterizations of the formulations. Similar data are presented for Herbicide Orange (2). Several additional formulations were characterized under EPA Contract No. 68-02-3174, Task 2, and these results are also presented in Table A-2.

The results presented in Table A-2 indicate that these formulations will burn better and have lower emissions than Herbicide Orange because of their:

- Higher heat content which provide for a higher temperature incineration
- Higher vapor pressures which result in more rapid evaporation after atomization in the flame
- Lower viscosities which make the silvex easier to pump, resulting in better atomization in the flame
- Lower chlorine content which results in lower HCl emissions.

Any additional silvex formluations should be characterized similarly. Because of the stringency typical of product formulation specifications, additional replicate characterization is unnecessary.

A.2 ADDITIONAL CHARACTERIZATION OF SILVEX

It is estimated (3) that there would be about 1.2 million gallons of

TABLE A-1. CONTENTS OF SILVEX FORMULATIONS

Manufacturer	Formulation Name	Formulation Contents
Chevron Chemical Company	ORTHO WEED-B-GON Lawn Weed Killer	21.4% Butoxy Propyl Esters of 2,4-D 10.0% Butoxy Propyl Esters of Silvex 68.6% Inert Ingredients
	ORTHO Chickweed and Clover Killer	13.8% Isooctyl Ester of Silvex 86.2% Inert Ingredients
	ORTHO Chickweed, Spurge and Oxalis Killer	15.1% Isooctyl Ester of Silvex 84.9% Inert Ingredients
J & L Adikes, Inc.	GRO-WELL Chickweed and Clover Killer	13.3% Isooctyl Ester of Silvex 86.7% Inert Ingredients
Rockland Chemical Company, Inc.	Professional Lawn Weed Killer "B"	29.1% Butoxy Propyl Esters of 2,4-D 14.1% Butoxy Propyl Esters of Silvex 56.8% Inert Ingredients
	Lawn Weed Killer "B"	16.3% Butoxy Propyl Esters of 2,4-D 7.9% Butoxy Propyl Esters of Silvex 75.8% Inert Ingredients
Ralson Purina Company	Purina Lawn Weed Killer	23.8% Isooctyl Ester of 2,4-D 11.0% Isooctyl Ester of Silvex 65.2% Inert Ingredients
Thompson-Hayward Company	Dead Weed for Lawns	9.4% Isooctyl Ester of 2,4-D 4.4% Isooctyl Ester of Silvex 86.2% Inert Ingredients (82.2%) Heavy Naphtha
Farmingdale Laboratories	Lawn Weed and Dandelion Killer	16.5% Butoxy Propyl Ester of 2,4-D 8.2% Butoxy Propyl Ester of Silvex 75.3% Inert Ingredients
	Silvex Chickweed and Clover Killer	Not available
Blackleaf Industries	Blackleaf Lawn Weed Killer	12.72% Dimethylamine Salt of 2,4-D 4.07% Dimethylamine Salt of Silvex 83.21% Inert Ingredients
	K-Mart Broadleaf Weed Killer	Not available
	Blackleaf Clover & Chickweed Killer	13.8% Isooctyl Ester of Silvex 86.2% Inert Ingredients
	K-Mart Clover and Chickweed Killer	Not available

TABLE A-2. COMPARISON OF GENERAL CHEMICAL AND PHYSICAL PROPERTIES OF SILVEX FORMULATIONS WITH THOSE OF HERBICIDE ORANGE (1,2)

Property	Herbicide Orange	Silvex Formulations				
		Chevron, Weed-B-Gon Lawn Weed Killer	Chevron, Chickweed and Clover Killer	Chevron, Chickweed Spurge and Oxalis Killer	J & L Adikes, Gro-Well	Rockland, Professional Lawn Weed Killer "B"
Btu Content per Pound	10,017	15,549	16,831	18,093	17 474	14,835
Physical State	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid
Color	Reddish brown to straw	Reddish brown	Reddish brown	Light yellow	---	Reddish brown
Appearance	Dark, oily liquid	Transparent liquid light oil viscosity	Transparent liquid light oil viscosity	Transparent liquid Slightly more viscuous than water	---	Transparent liquid light oil viscosity
Solubility	Soluble in fuels and organic solvents, insoluble in water	Soluble in water[a], fuels and solvents	Soluble in water fuels and solvents	Soluble in water, fuels and solvents	Soluble in water, fuels and solvents	Soluble in water, fuels and solvents
Freezing Point (°C)	7-9	<-80[b]	<-80	<-80	<-80	<-80
Flash Point (°C)	146	34	26	46	56	62
Specific Gravity @ 25°C	1.220 - 1.295	.9065	.9159	.8488	.9267	1.0028
Weight (lb/gal @ 25°C)	---	7.55	7.63	7.07	7.72	8.35
Vapor Pressure @ 30°C (mm Hg)	3.6×10^{-4}	8.60[c]	10.7[c]	11.2[c]	9.34[c]	10.7[c]
Viscosity, Centipoises						
@ 20°C	46	3.3	3.2	3.7	3.2	3.6
@ 30°C	24	2.9	2.9	3.0	2.8	2.8
@ 35°C	18	2.3	2.4	2.4	2.6	2.2
@ 40°C	14	1.9	2.0	1.9	2.2	1.9
@ 45°C	11	1.6	1.0	1.6	2.0	1.7
Elemental Composition (weight %)						
Carbon	49.11[e]	74.02	83.11	79.49	82.39	71.86
Hydrogen	4.65	11.12	8.99	12.91	9.93	8.71
Chlorine	29.87	7.26	4.31	4.58	3.90	10.38
Nitrogen	---	0.02	0.04	0.02	0.02	0.04
Sulfur	---	0.30	0.11	0.25	0.20	0.03
Oxygen[f]	16.37	6.70	3.08	2.24	3.50	8.79
Ash Content (weight %)	---	0.58	0.36	0.51	0.06	0.19

(Continued)

TABLE A-2. (continued)

Property	Silvex Formulations		Blackleaf Lawn Weed Killer	Blackleaf Clover & Chickweed Killer	Thompson-Hayward Dead Weed for Lawns	Farmingdale Laboratories Lawn Weed & Dandelion Killer
	Rockland, Lawn Weed Killer "B"	Purina, Lawn Weed Killer				
Btu Content per Pound	16,562	16,279	1,462	17,117	16,958	17,182
Physical State	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid
Color	Straw yellow	Yellow Amber	Reddish brown	Reddish brown	Reddish brown	Reddish brown
Appearance	Transparent liquid very light oil viscosity	Transparent liquid very light oil viscosity	Transparent liquid light oil viscosity	Transparent liquid light oil viscosity	Transparent liquid light oil viscosity	Transparent liquid light oil viscosity
Solubility	Soluble in water, fuels and solvents	Soluble in water, fuels and solvents	Soluble in water, fuels and solvents	Soluble in water, fuels and solvents	Soluble in water, fuels and solvents	Soluble in water, fuels and solvents
Freezing Point (°C)	<-80	<-80	-11	<50	-22	<50
Flash Point (°C)	51	51	50	53.3	47.8	39.4
Specific Gravity @ 25°C	.9478	.9478	1.055	0.940	0.935	0.882
Weight (lb/gal @ 25°C)	7.89	7.89	8.79	7.83	7.79	7.34
Vapor Pressure, mm Hg at 38°C	11.7[c]	10.1[c]	60.5[d]	43.95[d]	38.8[d]	56.9[d]
Viscosity, Centipoises						
at 20°C	3.6	3.4	1.44	2.95	1.57	3.1
at 30°C	3.8	3.0	1.05	2.34	1.42	2.35
at 35°C	2.2	2.6	0.85	2.05	1.19	2.17
at 40°C	1.9	2.3	0.80	1.87	1.04	1.85
at 45°C	1.7	2.0				
Elemental Composition (weight %)						
Carbon	79.56	74.72	8.44	82.14	83.83	77.40
Hydrogen	9.73	11.02	10.03	9.72	9.25	11.74
Chlorine	5.12	8.11	4.98	4.32	4.14	5.23
Nitrogen	0.02	0.02	0.82	0.04	0.13	0.06
Sulfur	0.21	0.24	0.12	0.09	0.06	0.16
Oxygen[f]	5.28	5.51	75.51	3.37	2.45	5.04
Ash Content (weight %)	0.08	0.38	0.10	0.32	0.14	0.37

[a] The solubility of the Silvex samples in water is due to the presence of emulsifiers in all formulations.

[b] None of the Silvex formulations froze at the temperature of dry ice/acetone (-80°C), however, they did gel in the range of -20° to -30°C.

[c] Measured at 30°C.

[d] Measured at 38°C.

[e] All elemental composition values for herbicide orange are theoretical, not measured.

[f] By difference.

liquid silvex formulations to be incinerated. Table A-3 presents the number and locations of containers of various silvex formulations provided to EPA(4) to date by Chevron Chemical Company. Table A-4 presents the amounts and locations of various silvex formulations provided to EPA(4) to date by other Registrants. Current best estimate data provided identifies 727,000 gallons of liquid silvex formulations at 35 various locations. An estimated average composition of the various silvex formulations to be incinerated is:

- 0.1% isooctyl 2,4-D
- 0.6% isooctyl 2,4,5-TP
- 20.4% butoxypropyl 2,4-D
- 9.6% butoxypropyl 2,4,5-TP
- $2 \times 10^{-6}\%$ TCDD
- 69.3% inert ingredients, chiefly kerosene

Content percentages were calculated using formulation compositions values from Table A-1 and current formula quantities given in Tables A-3 and A-4. Specific formulations will contain the isooctyl ester or the butoxypropyl ester compounds but will normally not contain both groups in one formulation.

A.3 DIOXIN CHARACTERIZATION

EPA has funded (Contract No. 68-01-3981) analyses of a number of technical grade pesticide formulations. The results were reported in Reference 5. Among these formulations were seven batches (unknown manufacturer and formulation) containing butoxypropyl esters of silvex and one formulation (unknown formulation and manufacturer) containing isooctyl esters of silvex. TCDD was detected in four of the seven butoxypropyl ester formulations and in the one isooctyl ester formulation. The results of these analyses were:

- 20.2 ± 1.5 ppb (range 19-21 ppb) TCDD in the butoxypropyl ester formulations
- 20 ppb TCDD in the isooctyl ester formulation.

TABLE A-3. NUMBERS OF CONTAINERS AT VARIOUS LOCATIONS(4)

	Chevron Chemical Co.										
	Weed-B-Gon						Chickweed and Clover Killer			Spurge and Oxalis Killer	
Location	8 oz	16 oz	32 oz	43-1/2 oz	1/2 gal	1 gal	8 oz	16 oz	32 oz	8 oz	16 oz
E. Los Angeles, CA	10,334	55,085	5,752	38	571	750	-	-	-	7,220	53,414
Richmond, CA	34,736	93,369	40,182	913	9,010	2,328	-	-	-	6,818	12,913
Tampa, FL	588	0	18	2	0	0	-	-	-	-	-
Atlanta, GA	10,823	47,194	45,192	4,895	5,257	3,348	1,241	5,224	728	-	-
Bensonville, IL	6,078	66,732	261,308	5,189	33,014	18,396	2,580	5,206	4,876	-	-
Danville, IL	11,121	36,424	205,525	43,860	17,977	17,342	10,637	9,265	3,701	-	-
E. St. Louis, IL	18,687	55,483	189,025	10,260	28,455	17,301	7,220	8,609	5,691	-	-
Livonia, MI	5,404	29,184	104,784	0	19,002	13,704	3,446	7,622	3,408	-	-
Jersey City, NJ	0	0	31,104	144	0	20	12	2,376	1,032	0	0
Metuchen, NJ	10,121	41,478	166,451	13,646	7,770	9,162	5,865	5,748	2,679	5	0
Chillicothe, OH	1,702	12,198	33,297	2,611	4,327	4,001	1,866	4,563	1,831	-	-
Lebanon, PA	8,693	42,884	144,229	7,879	10,486	10,981	5,484	9,398	4,933	4	12
Arlington, TX	14,011	71,390	27,268	689	6,211	2,887	717	5,468	160	-	-
Clearfield, UT	18,939	80,688	142,777	4,104	13,244	13,475	-	-	-	6,884	12,949

TABLE A-4. VOLUMES OF SILVEX FORMULATIONS AT VARIOUS LOCATIONS(4)

Location	Rockland Chemical Co.						J.C. Adikes Inc.	Ralston-Purina Co.	Farmingdale Laboratories		Blackleaf Industries			
	K-Mart Broadleaf Weed Killer (gal)	Lawn-a-Magic Weed Away +B (gal)	Lawn Weed Killer B (gal)	Professional Lawn Weed Killer B (gal)	Lawn Doctor Lawn Weed Killer B (gal)	Lawn Products Lawn Weed Killer B (gal)	Gro-Well Chickweed and Clover Killer (gal)	Lawn Weed Killer (gal)	Lawn Weed and Dandelion Killer (gal)	Silvex Chickweeds and Clover Killer (gal)	Blackleaf Lawn Weed Killer (gal)	K-Mart Broadleaf Week Killer (gal)	Blackleaf Clover and Chickweed Killer (gal)	K-Mart Clover and Chickweed Killer (gal)
Greenwich, CN				103										
Newman, GA	2,025													
Elgin, IL											← 15 - 20,000 →			
Ft. Wayne, IN	960													
Lawrence, KN	2,025													
Plymouth, MO	1,917													
St. Louis, MO								1350						
Sparks, NV	1,917													
Mahwak, NJ			38											
Morganville, NJ					60									
W. Caldwell, NJ	115		173	31	24	30								
Bellmore, NY														
Chenango Bridge, NY			3											
Farmingdale, NY									3,800	200				
Jamaica, NY							241							
Lake Katrine, NY			11											
Manchester, NY				40										
Plainview, NY		14												
Seaford, NY		20												
New Holland, PA			150											
Springfield, VA			24											

A.3.1 Additional Characterization for Dioxin

The assessment of an accurate average concentration value for dioxin in the liquid silvex formulations required recommendation of an effective program to collect and evaluate the various formulations so as to provide a statistically valid value. As the total of a particular manufacturer's lot is likely to be spread over several locations and into various sizes of containers, a statistically valid sampling and analysis scheme was designed to provide an accurate value of the TCDD content of the liquid silvex formulations. This section presents the approach taken to characterize the TCDD content of the silvex formulations.

The American Society for Testing Materials (ASTM) published(6) a procedure (ASTM 270-65) for sampling petroleum and petroleum products. Part of this procedure covers sampling package lots in shipments. Table A-5 reproduces Table 3 of this procedure. For a given number of containers in a shipment, Table A-5 specifies how many containers to sample for preparing a composite sample for analysis. If all silvex containers were segregated by manufacturer's lot, Table A-5 would have been used to determine how many containers in each lot would have had to have been taken to prepare a composite sample for TCDD analysis. Because information on manufacturer's lots was not available, the number of analyses required could not be specified.

The approach selected to characterizing the TCDD content of the silvex formulations involved treating all containers of a particular formulation at a particular location as a single manufacturer's lot. Information on lot-to-lot variation in TCDD content of a particular manufacturer's lot that was spread over several locations is not lost in this approach but is included in the overall variance of the weighted population average. The following example illustrates this approach. In Table A-3 it is seen that there were 72,530 containers of WEED-B-GON (8 oz. to 1 gal.) at E. Los Angeles, CA. Table A-5 shows that it was necessary to take 20 of these 72,530 containers (number of containers is greater than 6860) to form a composite sample for analysis. In Table A-5, it is seen that there were 29 formulation-location pairs. Thus, 29 analyses were necessary for Chevron Chemical Company products. Table A-4 shows that there were 29 formulation-

TABLE A-5. MINIMUM NUMBER OF PACKAGES TO BE SAMPLED FOR COMPOSITING*

No. Packages	No. to Sample	No. Packages	No. to Sample
1-3	All	1221-1728	12
4-64	4	1729-2197	13
65-125	5	2198-2744	14
126-216	6	2745-3375	15
217-343	7	3376-4096	16
344-512	8	4097-4913	17
513-729	9	4914-5832	18
730-1000	10	5833-6859	19
1001-1331	11	<6860	20

* From ASTM Procedure D270(6)

location pairs, and therefore, 29 analyses were necessary.

As additional registrants supplied information on their recalled product formulations, this sampling and analysis approach was applied.

Using this approach it was important that the sampling performed at the various locations assured a random selection and proportional number of containers from each of the different container sizes. For example, when there was a large number of containers in a formulation-location pair, as in the example above, not more than one container should have been taken from a case. Further, the number of containers taken for sampling should have included a proportional number from each different container size.

To perform the sampling at the various locations, the procedure below was followed. From data supplied to EPA from the Registrants, the appropriate number of containers to be sampled at each formulation-location pair was determined using Table A-5. At a given location, the appropriate number of containers was taken randomly, as described above. Each container selected was labeled with the formulation-location designation. The containers were packaged into a case which was also labeled with the formulation-location designation. The cases were labeled in accordance with pertinent Federal and State regulations for shipping pesticides and shipped to the designated EPA analytical laboratory for analyses.

The analytical laboratory prepared the composite samples prior to analysis by removing a given volume of silvex from each container of a formulation-location pair. After analysis, the cases were held until shipped to the decanning facility.

At the time of writing, an analysis plan illustrating analytical procedures and Quality Assurance/Quality Control program considerations that are in compliance with EPA's requirements had not been received from the analytical laboratory. As this information becomes available, it will be added to the final EIS.

A.3.2 Results

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APPENDIX B

SUMMARIES OF PERTINENT INCINERATION PROGRAMS

B. SUMMARIES OF PERTINENT INCINERATION PROGRAMS

B.1 AT-SEA INCINERATION OF HERBICIDE ORANGE(1)

Incineration of U.S. Air Force (USAF) stocks of Herbicide Orange took place in the Pacific Ocean approximately 120 miles west of Johnston Atoll. A total of 10,400 metric tons of waste was burned, requiring 714 hours. The average incineration rate was 14.5 metric tons per hour or 7.3 metric tons per hour per incinerator. For the three burns, the average flame temperature was 1500°C as determined by daily optical pyrometer measurements. The average incinerator wall temperature was 1273°C for the three burns. The average combustion effluent flow rate per incinerator was calculated to be 70,700 cubic meters per hour (dry gas at 20°C). Given these average conditions of combustion air and waste feed rates and temperature, the average calculated incinerator residence time was 1.0 second. The incinerator residence time was the time available for a waste molecule to be converted to combustion products.

A modified EPA Method 5 train (Lear-Siegler), which incorporated an organic vapor sorbent trap, and a USAF-OEHL benzene impinger train were used for stack sampling. The Method 5 train was used to acquire samples to be analyzed for organic species potentially present in the combustion effluent; it was also used as a backup to the USAF-OEHL train. The USAF-OEHL train was the primary train for acquiring samples for TCDD analysis. Stack samples were acquired by a remotely activated, water-cooled, stainless steel probe capable of traversing the starboard stack diameter of 3.4 meters.

Incineration effluent products were simultaneously monitored for total hydrocarbons, carbon monoxide, carbon dioxide, and oxygen. Concentrations of these species were measured in real time to monitor the overall combustion efficiency of the incinerator.

Data from the on-line analyzers and the results of the analyses of the stack samples were uOed to calculate incineration efficiencies. The on-line monitoring data was also used to calculate the combustion efficiency. Four different waste destruction efficiencies were calculated, one from the laboratory analyses. These incineration efficiency terms are defined in Table B-1. Average values for the incineration efficiencies are given in Table B-2.

Results of the analyses by TRW, Wright State University (WSU), and Battelle-Columbus Laboratores (BCL), and of the reduction of the on-line monitoring data indicate that the performance of the incinerators was greater than 99.9% in terms of combustion and destruction efficiencies for 2,4-D and 2,4,5-T, TCDD and total organic material.

The glass components used in the sampling train stood up well to the corrosive (HCl) combustion effluent. The stainless steel components previously used in sampling on the Vulcanus were corroded by the HCl.(2)

It was found that wall effects on the combustion effluent gas composition from Herbicide Orange incineration were nonexistent at distances greater than 10 cm from the inside incinerator wall surface. Therefore, incinerator combustion efficiency could be determined using a fixed position probe.

B.2 AT-SEA INCINERATION OF ORGANOCHLORINE WASTES (2)

In March of 1977, approximately 4100 metric tons of Shell Chemical Company wastes were incinerated onboard the M/T Vulcanus. This second burn in the Gulf of Mexico afforded an opportunity to use recent technology for monitoring and assessing the environmental effectiveness of this disposal process. Equally important was acquisition of data to support developing at-sea incineration regulations and guidelines for future incineration vessels.

TABLE B-1. DEFINITION OF INCINERATION EFFICIENCY TERMS

Efficiency Term		Method of Calculation
Overall combustion efficiency	DE_{CE}	$= 100 \text{ X } \frac{[\ \%\ CO_2\ ] - [\ \%\ CO]}{[\ \%\ CO_2\ ]}$
Total hydrocarbon (THC) destruction efficiency	DE_{THC}	$= 100 \text{ X } \frac{[\text{ THC fed }] - [\text{ THC found }]}{[\text{ THC fed }]}$
Herbicide Orange (HO) destruction efficiency	DE_{HO}	$= 100 \text{ X } \frac{[\text{ HO fed }] - [\text{ HO found }]}{[\text{ HO fed }]}$
TCDD destruction efficiency	DE_{TCDD}	$= 100 \text{ X } \frac{[\text{ TCDD fed }] - [\text{ TCDD found}]}{[\text{ TCDD fed }]}$
Chlorinated hydrocarbon (CHC)	DE_{CHC}	$= 100 \text{ X } \frac{[\text{ CHC fed }] - [\text{ CHC found }]}{[\text{ CHC fed }]}$

TABLE B-2. SUMMARY OF CALCULATED INCINERATION EFFICIENCIES

	First Burn	Second Burn	Third Burn	Combined 3 Burns
DE_{CE}	99.992	99.989	99.983	99.990
DE_{THC}	99.982	99.992	-(a)	99.985
DE_{HO}	>99.999	>99.999	>99.999	>99.999
DE_{TCDD}	>99.99	>99.88	>99.96	>99.93
DE_{CHC}	>99.999	>99.999	>99.999	>99.999

(a) HC Analyzer was inoperative during third burn

Wastes burned were a by-product of the manufacture of allyl chloride, epichlorohydrin, dichloroethane, and vinyl chloride at Shell Chemical Company's Deer Park, Texas plant. The material consisted primarily of low molecular weight chlorinated aliphatics and had a gross heat content of 3,860 kcal/kg (6,950 Btu/lb).

Sampling was done using a high volume EPA Source Assessment Sampling System (SASS) with a sampling rate of 0.085 cubic meters per minute. This SASS train was used to trap and remove organic vapors from the stack effluent. During stack sampling operations, incineration effluent products were simultaneously monitored for total hydrocarbons, carbon monoxide and dioxide, nitrogen oxide and dioxide, and oxygen concentrations. Analyses were done to determine how effectively the incineration process destroyed constituents in the organochlorine waste feed stock.

The waste was effectively destroyed, but the SASS sampling train, while advantageous for acquiring large sample volumes, was of marginal utility because of corrosion by HCl of the stainless steel construction.

The waste was burned at an average rate of 22 metric tons per hour or approximately 11 metric tons per hour for each incinerator. The average flame temperature was 1535°C as determined by optical pyrometer measurements. Total elapsed burn times was 186 hours and 45 minutes. Under these conditions, a combustion gas residence time in the incinerator was calculated to be approximately 0.9 seconds.

Six waste incineration sampling tests (I through VI) and one background test (VII) burning fuel oil alone were conducted. Analytical results as well as on-line total hydrocarbon measurements provided the basis for calculating waste destruction efficiencies. Five efficiencies were determined, each with separate means of sampling, analysis, and calculation. These five destruction efficiency terms are listed and defined in Table B-3. The resulting destruction efficiency values are presented in Table B-4 for tests IV through VII. The latter was the background or baseline test using fuel oil.

The results indicate that incineration efficiency was greater than 99.9 percent for both waste and total organic destruction.

TABLE B-3. DEFINITION OF DESTRUCTION EFFICIENCY TERMS

Efficiency Term	Method of Calculation
Overall combustion efficiency	$DE_{CE} = 100 \text{ X } \frac{[\%\ CO_2] - [\%\ CO]}{[\%\ CO_2]}$
Total hydrocarbon (THC) destruction efficiency	$DE_{THC} = 100 \text{ X } \frac{[\text{THC fed}] - [\text{THC found}]}{[\text{THC fed}]}$
Total organic destruction efficiency, grab gas (GG)	$DE_{GGHC} = 100 \text{ X } \frac{[\text{THC fed}] - [\text{THC, grab gas}]}{[\text{THC fed})}$
Waste destruction efficiency based on major components trichloropropane (TCP)	$DE_{TCP} = 100 \text{ X } \frac{[\text{TCP fed}] - [\text{TCP found}]}{[\text{TCP fed})}$
Waste destruction efficiency TCP in grab gas	$DE_{GGTCP} = 100 \text{ X } \frac{[\text{TCP fed}] - [\text{TCP, grab gas}]}{[\text{TCP fed}]}$

TABLE B-4. SUMMARY OF CALCULATED DESTRUCTION EFFICIENCIES

	Test Number			
	IV Waste	V Waste	VI Waste	VII Background
DE_{CE}	99.98 %	99.96 %	99.97 %	99.97 %
DE_{THC}	99.991 %	99.996 %	99.996 %	99.997 %
DE_{GGHC}	99.998 %	99.996 %	99.997 %	99.999 %
DE_{TCP}	99.98 %	99.92 %	99.98 %	-
DE_{GGTCP}	99.999 %[a]	99.999 %[b]	99.999 %[b]	-

a) Waste constituents not detected
b) Based on trace quantity of trichloropropane found

B.3 INCINERATION OF ORGANOCHLORINE WASTES AT SEA (3)

In October of 1974, 4,200 metric tons of organochlorine wastes were incinerated in Research Burn I. In December of 1974, 4,200 more metric tons were incinerated in Research Burn II. The remaining wastes were incinerated in two loads, on December 19-26 and December 31, 1974 - January 7, 1975 after EPA issued an interim permit. These wastes were from Shell Chemical Company, Deer Park, Texas. EPA, under the authority of the Marine Protection, Research and Sanctuaries Act conducted the study. The basic requirements of the permits were that at least 99.9 percent of the waste must be destroyed in the incineration. Using specially designed water-cooled probes, the incinerator effluents were collected in impingers and analyzed chemically. Instruments were also used to monitor unburned hydrocarbons and organic chlorides, hydrogen chloride, chlorine, oxygen, and carbon monoxide. Combustion temperatures and feed rates were also observed. Experimental difficulties during the first of the two burns prevented monitoring for periods of times deemed optimal; but, because of improved apparatus, monitoring was more complete during the second burn.

The feed rates and incinerator temperatures were within the ranges specified by the permits. Oxygen concentrations in the effluent gases indicated about 100 percent excess air was used during combustion. This is the range allowed by the permits and which permitted high combustion efficiencies. The measurements of organic carbon in the scrubbers and measurements with a total hydrocarbon analyzer showed the combustion efficiency to be 99.92 - 99.98 percent, safely more than the 99.9 percent required. Generally, trace organic chlorides were not observed. Based on the limit of detection of the analytical procedure, destruction of organic chloride was 99.984 - 99.998 percent complete. 99.9 percent was required by the permit. Low concentration of carbon monoxide (25-210 ppm) observed in the effluent gas were consistent with a highly efficient combustion process. The permit allowed concentrations up to 1000 ppm. Chlorine concentrations ranged upwards to 890 ppm. This was the expected raise and did not present any hazard. Emissions from both incinerators were similar; and, judging from crude traverse experiments, the location of the probe did not have a significant effect on the values measured. The recovery efficiency of the sampling system for a typical organic chloride in the waste (1,2-dichloroethane) in the low ppm range was 72 percent in a shipboard test and 90 percent in a laboratory test. Both values were greater than the 50 percent required by the permit. From results observed, it is apparent that the incinerators on the Vulcanus are highly efficient (>99.9 percent) in the combustion of organic chloride wastes.

B.4 SMALL SCALE INCINERATION STUDIES OF HERBICIDE ORANGE

This section summarizes small scale studies done on the incineration of Herbicide Orange.

Mississippi State University (4) studied the temperatures required for complete thermal degradation of the herbicide products and the volatile gases containing dioxin (TCDD) and evaluated suitable scrubbing agents to remove toxicants from the effluent. To incinerate the herbicide samples, they were placed in ceramic combustion boats which were then placed in a silica combustion tube. The tube was then placed in a resistance-type furnace. Commercial oxygen or air was passed through the tube at a prescribed rate. A series of experiments were conducted at various temperatures, 700 to 1000°C to determine chloride recovery, particulate recovery, scrubber efficiency, and carbon monoxide and carbon dioxide recovery. Experiments were also conducted for mass spectograph analysis of exhaust gas samples, extracts of particulate filters, and phytotoxicity analysis.

The USAF Environmental Health Laboratory, Kelly AFB in Texas conducted experiments (5) to determine the feasibility of using gas liquid chromatography alone to analyze combustion gases and scrubbing blow-down water for the herbicide esters and TCDD and developing efficient methods of extracting the normal butyl esters and TCDD from gaseous and water discharges.

The incineration chamber consisted of a Vycor-Pyrex tube placed in a Lindberg heavy duty furnace equipped with heating elements capable of operating at 1200°C.

The Marquardt Company, Van Nuys, California, conducted experiments to determine the feasibility of incinerating herbicide using the Marquardt Sudden Expansion (SUE)® burner.(6) Particular emphasis was placed on the ability to destroy the trace quantities of dioxin, the herbicide itself, and to determine the nature and extent of the undesireable components in the exhaust gases and in the scrubbing liquid used to cool and scrub the exhaust gases. Incineration was done in a SUE burner. The samples were analyzed by gas chromatography and mass spectroscopy.

The Marquardt Company and the USAF Environmental Health Laboratories conducted(7) tests to determine the ability to destruct Herbicide Orange in an incinerator; determine the engineering data necessary to monitor, control, and document the incineration operation; evaluate the effects and project the long term effects of the combustion gases on the material of the incinerator unit; determine the combustion gas, scrubbed effluent gas, and "spent" scrubber water discharge mass rates of herbicide constituents and any other organic compounds which may be detected; determine the presence of herbicide pyrolyzates and hydrolozates; determine the toxicity of "spent" scrubber water to aquatic indicator organisms; evaluate the noise produced by an incinerator system; and evaluate the effectiveness of a proposed drum cleaning procedure.

The results of these tests concluded that incineration is an effective method to destroy large amounts of Herbicide Orange. The essentially complete destruction of the herbicide components dictates that the effect of combustion gases will be minimal to non-existent, and could be discharged into a remote, non-vegetative environment. The hydrogen chloride generated by the incineration process is phytotoxic; the removal of hydrogen chloride via alkaline scrubbing is extremely efficient and also removes particulates from the combustion gas. The discharge of spent scrubber water will require consideration for its impact on the receiving water. All the reviewed projects revealed the TCDD concentration in the exhaust streams to be non-detectable or extremely small. Under high temperature incineration, destruction efficiencies of 99.9 to 99.999 appear feasible. Data indicate that pyrolyzates and hydrolyzates are minimized with efficient, high temperature incineration. It is concluded that incineration, with proper concern for the environment in which such incineration takes place, is an environmentally safe method for disposal of Herbicide Orange.

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APPENDIX C

TRANSPORTATION REQUIREMENTS

C. TRANSPORTATION REQUIREMENTS

Federal laws and regulations governing the transportation of liquid silvex formulations are discussed below. No attempt has been made to research state laws and regulations which may be applicable. Such research must be done when a disposal site is selected.

Regulatory authority over transportation of hazardous materials is vested in the Department of Transportation (DOT) and the EPA. DOT's current Hazardous Materials Regulations only apply to transporters engaged in interstate or foreign commerce and the shippers that use them*. However, regulations proposed by EPA (43 FR 18506) under section 3003 of the Solid Waste Disposal Act would require that when a material is hazardous according to both DOT and EPA definitions, provisions of the DOT regulations must be complied with for intrastate as well as interstate transportation. A proposed exception is that EPA regulations would not apply to transportation of hazardous waste(s) on the site of a permitted hazardous waste management facility.

Transportation of liquid silvex formulations from decanning facility to ship loading site by rail tank car or tank truck would likely come under DOT control, if proposed EPA regulations are promulgated. Transport by pipeline appears to be outside the scope of the previously mentioned DOT or EPA regulations. DOT regulates pipeline transport under 49 CFR 195 (Transportation of Liquids by Pipeline). This code generally specifies pipeline design criteria based on ANSI Standards B31.4 and B31.8. It will probably not be applicable to intrastate transport of hazardous wastes.

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*DOT regulations applicable to transporters are found in the Code of Federal Regulations Title 49, parts 171 (General Information, Regulations and Definitions), 174 (Carriage by Rail), 176 (Carriage by Vessel), 177 (Carriage by Public Highway). Bulk shipments by vessel are governed by 49 CFR 30-40 (Tank Vessels) and 49 CFR 98 (Bulk Cargos). Other regulations concerning shipping papers, labeling, marking, monitoring, reporting of spills, etc., may also be applicable (49 CFR 100-189).

EPA regulations proposed under the Solid Waste Disposal Act would also require development of a contingency plan to minimize damage to human health or the environment in the event of release of liquid silvex formulations during any part of the disposal operation, including transportation. Should a spill occur, the transporter would be required to initiate emergency notification procedures and to file a written report to DOT pursuant to 49 CFR 171.16.

APPENDIX D

DESCRIPTION OF THE M/T VULCANUS

D. DESCRIPTION OF THE M/T VULCANUS (1)

This section describes the M/T Vulcanus which is currently the largest and most extensively tested chemical waste incinerator ship in operation. This section is taken verbatim from Reference 1.

D.1 GENERAL LAYOUT OF VESSEL

The M/T Vulcanus, originally a cargo ship, was converted in 1972 to a chemical tanker fitted with two large incinerators located at the stern. The vessel meets all applicable requirements of the Intergovernmental Maritime Consultative Organization (IMCO) concerning transport of dangerous cargo by tanker. Figure D-1 is a picture of the vessel, and Table D-1 gives some of the ship's specifications. Both the picture and the table were furnished by Ocean Combustion Services, B.V., Rotterdam, The Netherlands, who manage the vessel.

Because of her size — an overall length of 102 meters, a beam of 14.4 meters, and a maximum draft of 7.4 meters — the Vulcanus is able to operate worldwide. Two diesel engines drive a single propeller to give cruising speeds of 10 to 13 knots. Her crew numbers 18; twelve to operate the vessel and six to operate the incinerators.

D.2 TANKS AND PUMPS

The Vulcanus is a double-hull, double-bottom vessel. Waste is carried in 15 cargo tanks which range in size from 115 to 574 cubic meters (m^3) with an overall capacity of 3503 m^3. Figure D-2 is a schematic of the cargo tank layout. Tanks are filled through a manifold on deck using a dockside loading pump. During normal operation the waste tanks can be discharged only through the incinerator feed system. There is, however, provision for discharging the cargo into the ocean if an emergency arises. Piping system construction makes it possible for any tank to be connected to either incinerator and for cargo to be transferred from one tank to another.

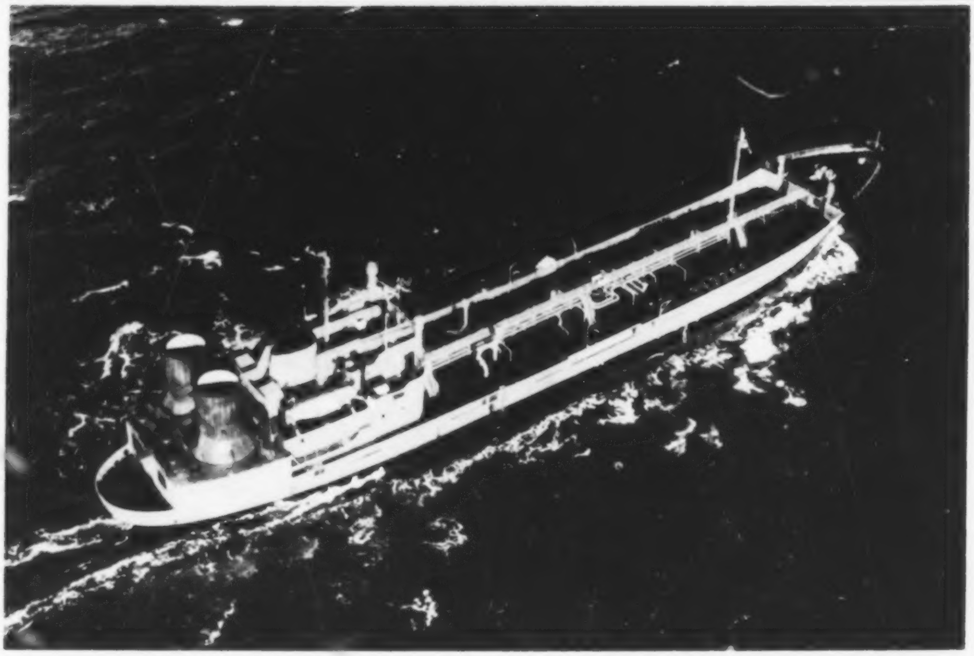

Figure D-1. M/T Vulcanus - incineration vessel.

The space between the two hulls is used for ballast. Ballast tanks are filled with seawater and emptied independently as required to trim and balance the ship. Fuel oil is carried in tanks under and in the engine room. The engine room is separated from the cargo tanks by double bulkheads. The pump room and generator room are situated between the engine room and the waste tanks.

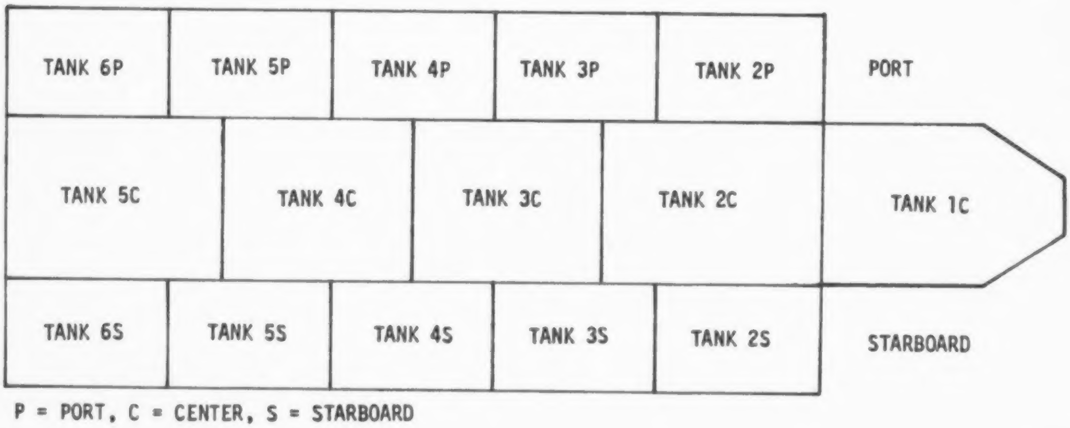
TANK 6P
TANK 5P
TANK 4P
TANK 3P
TANK 2P
PORT
TANK 5C
TANK 4C
TANK 3C
TANK 2C
TANK 1C
TANK 6S
TANK 5S
TANK 4S
TANK 3S
TANK 2S
STARBOARD
P = PORT, C = CENTER, S = STARBOARD

Figure D-2. Cargo tank layout schematic.

D.3 INCINERATOR SYSTEM

Waste is turned in two identical refractory-lined furnaces located at the stern. Each incinerator consists of two main sections, a combustion chamber and a stack, through which the burning gases pass sequentially (Figure D-3). This dual chamber configuration, which is characteristic of most high intensity combustion systems, uses the first chamber for internal mixing and the second for adequate residence time. Table D-1 gives characteristics of the incinerators.

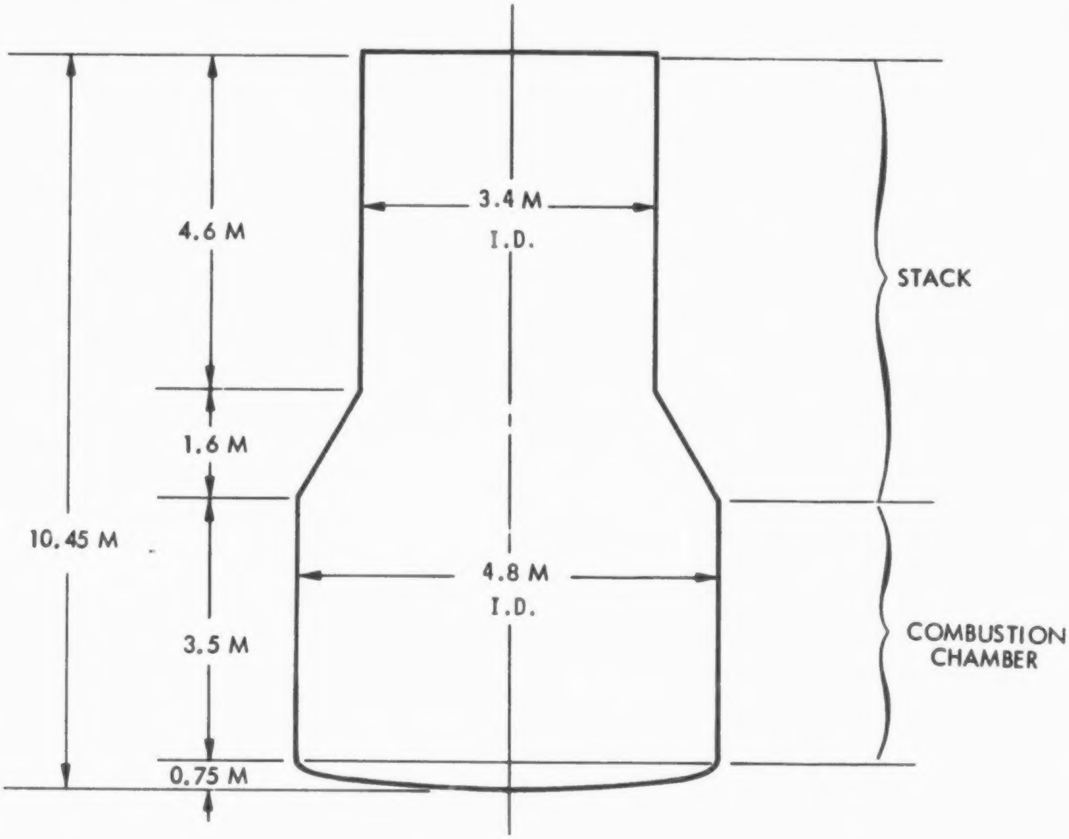
3.4 M
I.D.
4.6 M
STACK
1.6 M
10.45 M
4.8 M
I.D.
3.5 M
COMBUSTION CHAMBER
0.75 M

Figure D-3. Incinerator configuration.

TABLE D-1. SPECIFICATIONS OF THE M/T VULCANUS

Length overall	101.95 meters
Breadth	14.40 meters
Draft, maximum	7.40 meters
Deadweight (DWT)	4,768 metric tons
Speed	10-13 knots
Tank capacity	3,503 cubic meters (cu m)
Number of tanks	15, ranging in size from 115 cu m to 574 cu m
Tank coating	No coating in tanks, pipes, pumps, etc. All equipment consists of low carbon steel
Loading equipment	Not available, but can be placed on board, if required
Hose connection	10.2, 15.2, and 20.3 centimeters (4,6, 8 inches)in diameter
Safety equipment	Specially designed for this task and in accordance with latest regulations of IMCO, Scheepvaart-Inspectie (The Hague)
Waste to be processed	Must be liquid and pumpable. May contain solid substances in pieces up to 5 centimeters in size. Must not attack mild steel
Incinerators	2
Per incinerator:	
Overall height	10.45 m
Combustion chamber	
OD	5.5 m
ID	4.8 m
Stack (top)	
OD	3.8 m
ID	3.4 m
Waste feed (max)	12.5 metric tons/hour
Combustion air (max)	90,000 m^3/hour
Burners (Vortex type)	3
Volume	120 m^3
Residence time	1.0 sec at 1500 °C (calculated)

Combustion air is supplied by large fixed speed blowers with a rated maximum capacity of 90,000 cubic meters per hour for each incinerator. Adjustable vanes are incorporated in the combustion air supply system. When they are deflected, system pressure drop is increased, and the flow rate is reduced. Although no instrumentation is installed to monitor air flow rate, normal operation is stated by the ship's chief engineer to be between 75,000 and 80,000 cubic meters per hour at ambient conditions.

Liquid wastes are fed to the combustion system by means of electrically driven pumps. Upstream of each burner supply pump is a device (Gorator) for reducing the solids in the waste to a pumpable slurry. The Gorator also acts as a mixing pump by recirculating the waste through the waste tanks. Power for the blowers, pumps and other parts of the incinerator system is supplied by two diesel generators with a total capacity of 750 kW at 440 volts and 60 hertz.

Three burners of the vortex type are located at the same level on the periphery of each furnace near its base. The burners are of a totating cup, concentric design and delivery waste or fuel oil through a central tube to an atomization nozzle, where it meets high velocity air delivered through an annulus. The burners are positioned as shown in Figure D-4.

Three-way valves are utilized on each burner to provide either waste feed, fuel oil feed, or a shutoff condition. Waste and fuel oil cannot be valved into a burner simultaneously; however, alternate burners could be operated with fuel and waste to achieve higher or lower combustion temperatures if necessary, depending on the relative heat contents of the fuel oil and waste.

Periodically the burners require cleaning. They are normally cleaned one at a time with the remaining two firing waste. Cleaning is easily accomplished because the burners are readily accessible. Each burner has a vertical pivot so that it can be swung out of the furnace. The opening left by this operation is temporarily closed by a cover. The burners are cleaned by a metal tool which is pushed through the burner.

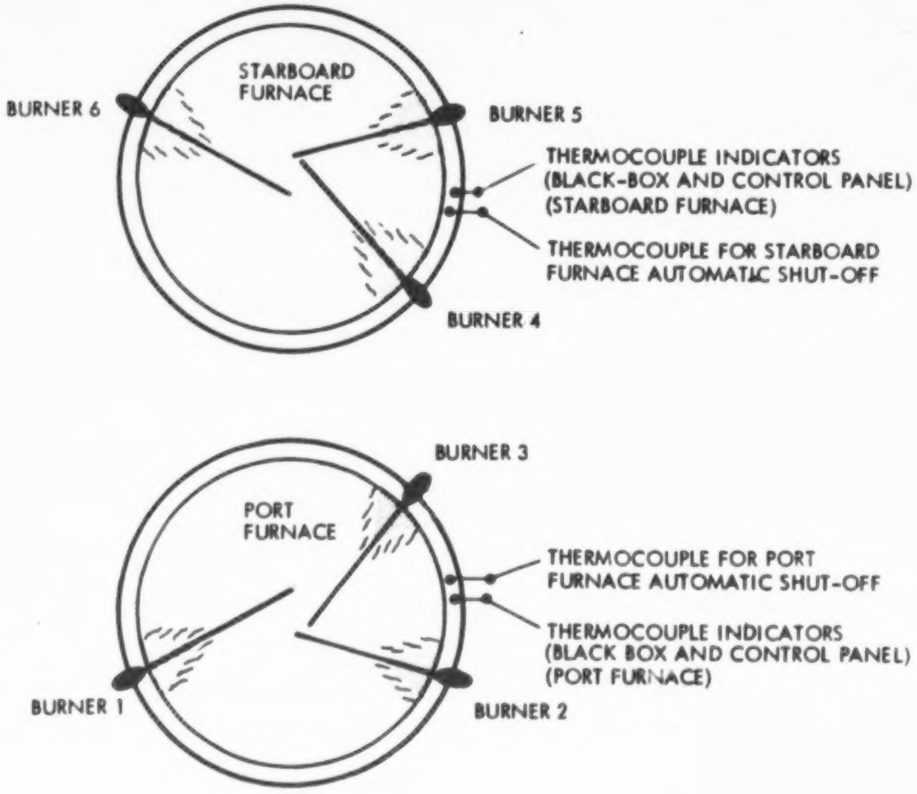
STARBOARD FURNACE
BURNER 6
BURNER 5
THERMOCOUPLE INDICATORS (BLACK-BOX AND CONTROL PANEL) (STARBOARD FURNACE)
THERMOCOUPLE FOR STARBOARD FURNACE AUTOMATIC SHUT-OFF
BURNER 4
BURNER 3
PORT FURNACE
THERMOCOUPLE FOR PORT FURNACE AUTOMATIC SHUT-OFF
THERMOCOUPLE INDICATORS (BLACK BOX AND CONTROL PANEL) (PORT FURNACE)
BURNER 1
BURNER 2

Figure D-4. Incineration system - burner and thermocouple locations.

D.4 RECORDING AND CONTROL EQUIPMENT

D.4.1 Waste flow measurements. Sounding the depth of waste in each tank with a tape is the usual method of determining burn rate. This method is only useful in port or in calm seas (i.e., minimum ship roll). During the actual burns, the total time is recorded for emptying each tank and a time averaged waste feed rate was determined.

Reference 1 described recent testing of several continuous waste flow measurement devices onboard the M/T Vulcanus. These instruments were an ultrasonic flow meter which was affixed to the outside of waste carrying pipes and a vortex shedding flow meter, the sensing element of which was installed inside waste carrying pipes. The sensor packages were in the incinerator room, the electronic packages were installed in a cabin. Both units functional well over a period of several months. The ultrasonic unit is preferable because it mounts on the outside of waste flow pipes and is thus not susceptible to plugging or erosion by the waste.

IMCO regulations will require capability for continuous waste flow measurement when the regulations take effect. It is recommended that this capability be installed and used for this incineration project.

D.4.2 Wall temperature measurements. Temperatures during operation of the incinerators are measured by three platinum-platinum/10% rhodium thermocouples in each incinerator. Two are located in a well opposite one of the burners (Figure D-4). One thermocouple is located approximately 1.3 cm from the inside surface of the refractory lining. This thermocouple provides temperature information to the automatic waste shut-off system and is called the controller thermocouple. The second thermocouple, approximately 4 cm from the inner surface of the firebrick, is referred to as the "indicator" because it provides temperature information to a panel located in the incinerator control room and to a panel ("black box") located on the bridge. The third thermocouple is mounted in each stack about 1 foot above the junction of the conical section with the vertical section of the stack. Temperatures indicated by the stack thermocouple are also displayed by the "black box".

The thermocouples used to activate the automatic waste shutoff system and the recording equipment have been quite reliable and durable according to personnel of the M/T Vulcanus.

D.5 EMERGENCY AUTOMATIC WASTE SHUTOFF

The following description of the automatic waste shutoff system utilized by the M/T Vulcanus is based upon verbal description of the system by the ship's engineering staff.

The waste shutoff system consists of a number of different components which can effect the closing of spring loaded solenoid valves which shut off waste flow to each burner and simultaneously shut off power to the waste pumps. These spring loaded solenoid valves are normally closed. During incineration, the valves are held open by an electrically induced magnetic field. The waste flows through the solenoid valves until the electrical current is interrupted by a malfunction in the incineration system. Once interrupted, the malfunction must be repaired and restart procedures implemented before incineration can continue. These restart procedures require fuel oil startup if the incinerator temperature has dropped below a specified minimum temperature.

The automatic waste shutoff system will stop waste flow (or fuel oil flow) to the affected burner(s) and shut off power to the waste pumps when any one of the following malfunctions occur:

- Waste pump overload
- Combustion air fan motor overload
- Burner pump overload
- Steering air (directs and shapes burner flames) or combustion air failure to reach an incinerator burner
- Open burner: A mechanical switch interrupts the electrical current when the burner swings open away from the incinerator wall (usually opened to remove residue during burner cleaning).
- Flame out: A light sensing resistor is located directly above each burner to monitor the flame. This resistor operates by viewing the flame and amplifying and conditioning the signal. Output of the sensor opens and closes several sets of contacts, half of which are normally closed and half normally open (under no flame condition). The normally closed contacts are not used in this system. Wires which conduct the electrical current used to induce the magnetic field for the waste shutoff valve are connected to the normally open position. During stable incineration the contacts are closed, and the electrical current flows through the contacts, completing the circuit which produces the magnetic field holding the waste shutoff valve open. Upon flame blockage or electrical failure, the contacts connected will return to normally open position, breaking the electrical current and removing the magnetic field from the waste valve, which in turn shuts by spring action.
- Temperature drops below minimum acceptable temperature: A thermocouple-controlled sensor interrupts the waste shutoff valve electrical current when the incinerator temperature drops below a preselected minimum temperature. The system used is the Plastomatic 2000 (supplied by Withoff-Philips, Bremen, West Germany), previously discussed in References 1-4.

Once the flow has been stopped by the automatic shutoff system, any malfunctions are repaired, and the following restart procedures are implemented:

- Manually restart waste pumps (or start fuel oil pumps if incinerator temperatures are low enough to require fuel oil startup)
- Depress ignitor button to provide ignition flame

- Manually open emergency shutoff valve to initiate waste (or fuel oil) flow to burner
- After stable combustion is attained, deactivate manual override of the emergency shutoff valves to return to automatic shutoff control condition.

D.6 SPECIAL EQUIPMENT

Certain equipment has been installed on the Vulcanus because of its particular type of operation. These items of equipment are:

- Loran and Decca Navigational Systems: This equipment is needed in American (Loran) and European (Decca) waters in order to locate the ship precisely at all times. Celestial navigation was used to locate and keep the Vulcanus in the designated burn zone.
- Anemometer: This equipment measures the velocity and force of the wind. It is, therefore, useful in selecting an attitude of the ship during various wind conditions such that the plume may be directed away from the ship and its personnel.
- Radio Communication: The Vulcanus is equipped with SSB (single side band) and DSB (double side band) radio for voice and continuous wave communication; MF (medium frequency) and SF (short wave) telegraphy; Marifoon (VHF) (all channels) for close-in voice communication; and Semafoon (a private telephone communication system). For this program, a Hagenuck Synthesized Transceiver should be installed to permit voice communication over all marine frequencies. A radio is also located on the bridge so that the watch officer can hear marine broadcasts at all times.
- Optical Pyrometer: A portable optical pyrometer will be used during the test program to measure incinerator flame temperatures. These measurements will be taken daily using a Leeds and Northrup optical pyrometer operating in the 6500 Å range.
- Black Box: On the bridge is a panel in a sealable enclosure referred to as the "black box" which displays information necessary to assure that wastes were being burned at proper temperatures and, in Europe where the Decca Navigator can receive suitable land-based signals, at the proper location. The panel displays include the following information: indicator thermocouple readings for each incinerator; stack thermocouple readings for each incinerator; day, month, and time; status (on/off) of the waste pumps; and the vessel's position by the Decca Navigator. An 8 mm movie camera within the black box is used to photograph the panel every 15 minutes during incinerator operations. Films from the incineration of silvex herbicide will be retained by the U.S. EPA.

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APPENDIX E

PLUME DISPERSION MODELING

E. PLUME DISPERSION MODELING

In order to evaluate air pollution impacts from the incineration emissions, it was necessary to approximate the concentrations in the air that would result from these emissions. This was done by using a standard Gaussian dispersion model with appropriate input parameters for each of the three alternatives considered by this study (i.e., land-based incineration, at-sea incineration in the Gulf of Mexico, and at-sea incineration along the North Coast). Details of this model are discussed below, and the input parameters are defined. Numerical results of the analysis are presented here in detail, but discussions of their significance will be found in the main body of this report, primarily in Section 4. The techniques employed are very similar to those described in a previous document entitled "Environmental Assessment: At-Sea and Land-Based Incineration of Organochlorine Wastes" (1).

E.1 MATHEMATICAL DESCRIPTION OF THE MODEL

Each of the three alternatives was modeled by assuming a point source at a given elevation and an approximately cone-shaped dispersion of the pollutants emanating from this source. The rate of dispersion is dependent on ambient factors such as wind speed and atmospheric stability. This is expressed mathematically through the following Gaussian dispersion equation.

$$\chi(x,y,z) = \frac{Q}{2\pi u \sigma_y \sigma_z} \quad X \quad A(y,\sigma_y) \quad X \quad B(z,H,\sigma_z)$$

where:

$$A(y,\sigma_y) = \exp - (y^2/2\sigma_y^2)$$

$$B(z,H,\sigma_z) = \exp\,[-(z-H)^2/2\sigma_y^2] + \exp\,[-(z+H)^2/2\sigma_y^2]$$

all symbols are defined in Table E-1.

TABLE E-1. DEFINITION OF SYMBOLS USED IN THE PLUME DISPERSION MODEL

$\chi(x,y,z)$ = pollutant concentration at coordinates x,y, and z.

x = downwind distance along centerline of plume
y = lateral coordinate
z = vertical coordinate

Q = mass emission rate from source
π = circular constant
u = wind speed
H = effective stack height

σ_y = lateral standard deviation of the plume
σ_z = vertical standard deviation of the plume

h = physical stack height
T = absolute temperature of ambient air
T_s = absolute temperature of stack gas
w = stack gas effluent velocity
r = stack radius at exit

The first term in the Gaussian dispersion equation accounts for the concentrations along the centerline of the plume. The second term accounts for lateral deviations from the certerline, and the third term accounts for vertical deviations. Therefore, to consider the specialized case of ground level concentrations beneath the centerline of the plume, the following terms will apply:

$$A(y,\sigma_y) = 1$$

$$B(z,H,\sigma_z) = 2 \exp\left[-{}^{1}/{}_{2}(H/\sigma_z)^2\right]$$

and:

$$X(x,o,o) = \frac{Q}{\pi U \sigma_y \sigma_z} \exp\left[-{}^{1}/{}_{2}\left(\frac{H}{\sigma_z}\right)^2\right]$$

The parameters σ_y and σ_z are both functions of downwind distance (x) and atmospheric stability category. Closed form equations are available for determining these values.

For the purposes of modeling, the "point source" at which pollutants are assumed to be emitted is not necessarily the same as the physical stack outlet. Such factors as initial exit velocity and elevated temperature of the stack gas contribute to considerable plume elevation before any substantial dispersion occurs. Therefore, the height of release given in the Gaussian dispersion equation is really representative of a virtual point source and is termed the effective stack height. Mathematically, it can be given by an equation suggested by Briggs (2):

$$H = h + 2.6\left\{\frac{T(T_s - T)\ wr^2}{T_s u(0.00508)}\right\}^{1/3}$$

Refer once again to Table E-1 for definition of variables.

E.2 LIMITATIONS AND ASSUMPTIONS OF THE MODEL

The Gaussian dispersion model is probably the best technique currently available for estimating plume dispersion. However, there are some underlying assumptions which should be kept in mind whenever using results from such an analysis. Also, there are some peculiarities specific to this application which should be addressed. These issues are discussed below.

The model does not account for gravitational settling, chemical reaction in the plume, or deposition mechanisms at the sea or land surfaces. Thus, any constituent of the plume subject to gravitational acceleration will fall out in a manner totally unrelated to Gaussian dispersion. Even when the plume itself impacts the land or sea surface, no deposition of material is taken into account (i.e., perfect reflectivity is assumed). This may be reasonable for dispersion over a solid land mass, but it is clearly not the case for a plume over water. For instance, the high aqueous solubility of HCl will cause the majority of it in contact with the water surface to dissolve, thus removing some HCl from the gaseous phase. This will cause an overprediction of gaseous HCl concentrations and probably those of the other constituents as well, depending on their solubility in water.

Finally, the stability categories commonly used for this kind of analysis have been developed based on dispersion characteristics over land. It has been known for some time that dispersion over water is considerably different than that over land for comparable stabilities. This is due to the dynamic nature of the sea surface and differences in the density stratification over water, as influenced by the presence of water vapor flux in addition to the heat flux experienced over land. Although these effects have not yet been quantified, the general result would be less rapid diffusion over water than over land.

E.3 MODEL INPUTS

Table E-2 presents all the input values used for this analysis, including emission factors for HCl; silvex; 2,4-D; and TCDD; the four pollutant constituents of primary interest. Section E.5 presents calculations of these quantities. These emission factors are based on the highest possible waste feed rates from the land-based and at-sea incineration hardware. The Rollins incineration facility in Deerpark, Texas was used as an example of a land-based incinerator, and the M/T Vulcanus was modeled as the seagoing option. The operation conditions associated with these mass flow rates were also used, specifically the gas exit velocity. It was assumed that the entire chlorine content of the waste was converted to HCl, and that 99.9% of all organics were destroyed. Also, the scrubber efficiency for the Rollins facility was determined to be 99.5% removal of HCl from the stack gas. No removal of trace organics was considered.

All meteorological parameters represent prevailing conditions as discussed in the sections in Section 3 of this report describing the affected environment. For the at-sea incineration alternatives, absolute ambient wind speeds were used rather than the relative wind speed with respect to the ship. Once departed from the moving ship, the plume will have very little inertia of its own and will quickly slow down to the ambient wind speed. Since no stability class information is available for the ocean incineration sites, the prevalent stability class for nearby coastal cities was chosen as the most representative data available. The "D" stability class is most prevalent in both the Gulf Coast and North Coast areas. This was the stability class used for the land-based alternative. For

TABLE E-2. INPUT PARAMETERS USED FOR PLUME DISPERSION MODELING

Input Variable	Land-Based Incineration	At-Sea Incineration Gulf of Mexico Site	At-Sea Incineration North Coast Site
Mass Emission, Q (g/sec):			
HCL	.27	240.0	240.0
*Silvex Equivalent	0.05	0.23	0.23
*2,4-D Equivalent	0.10	0.45	0.45
TCDD	1.42×10^{-8}	6.4×10^{-8}	6.4×10^{-8}
Atmospheric Stability Class	D	E	E
Wind Speed, u (m/sec)	5.0	7.5	8.5
Ambient Air Temperature, T(°K)	288.3	294.3	284.8
Physical Stack Height, h (m)	30	15	15
Stack Gas Temperature, T_s (°K)	333	1473	1473
Gas Exit Velocity, w (m/sec)	8.7	11.0	11.0
Effective Stack Heigh, H (m)	90	170	160

* The equivalent forms consist of a single aromatic ring, as opposed to the ester forms, i.e., the acids.

the at-sea operations, Class E was assumed in order to account to some degree for the reduced dispersion observed over water. Class D represents a neutral atmosphere, and Class E represents a slightly stable atmosphere.

E.4 RESULTS OF THE ANALYSIS

Figures E-1 through E-4 present graphical results of the modeling for the three incineration alternatives for 2,4-D; 2,4,5-T; TCDD; and HCl. A detailed discussion of the significance of these estimates may be found in sections of the main body of this report dealing with environmental consequences and air impacts in Section 4. Overall, pollutant dispersion is much better for the at-sea incineration cases, largely owing to a higher effective plume height. Still, HCl concentrations are lower for the land-based alternative because of wet scrubbing of the flue gas. In general, the concentration peak is closer to the source and more pronounced in the land-based alternative, whereas the concentrations for the at-sea alternatives have wider peaks which occur farther away from the source. These effects are characteristic of the differences between "D" and "E" stability categories. The original numerical results are also provided in tabular form. Tables E-3 through E-5 show concentrations of the four pollutant constituents for each of the three incineration alternatives.

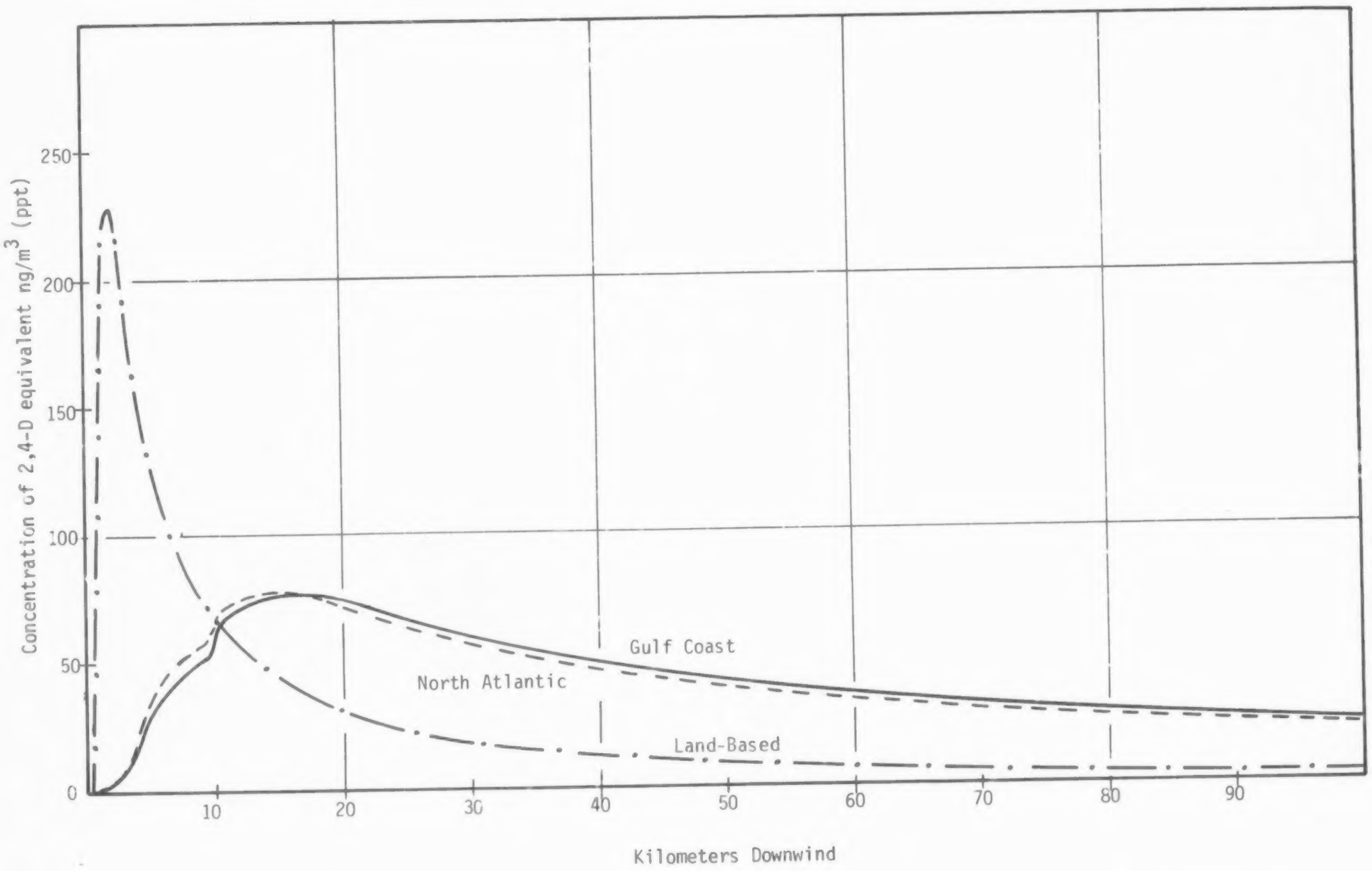

Figure E-1. Maximum downwind concentrations of 2,4-D.

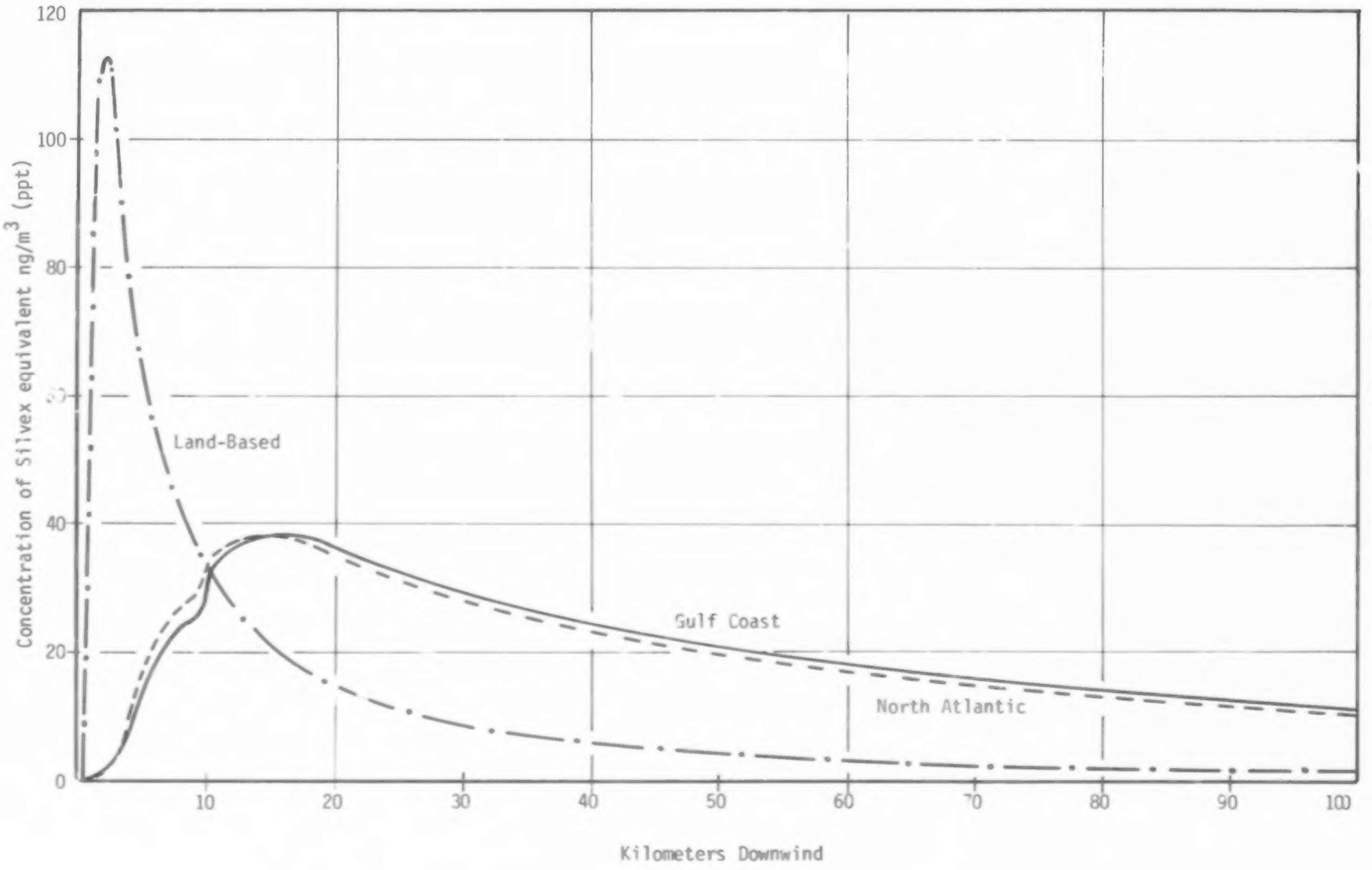

Figure E-2. Maximum downwind concentrations of 2,4,5-TP.

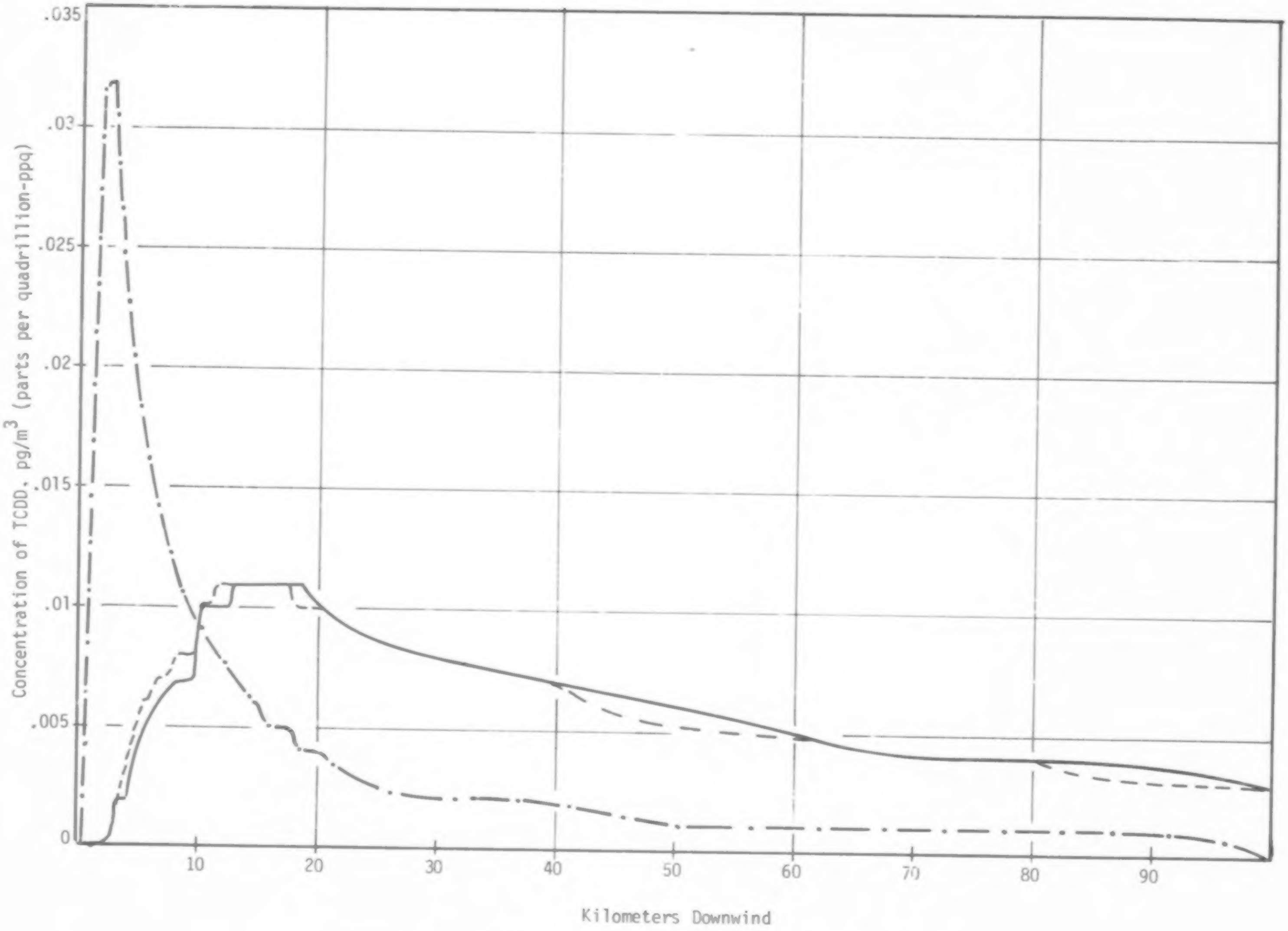

Figure E-3. Maximum downwind concentrations of TCDD.

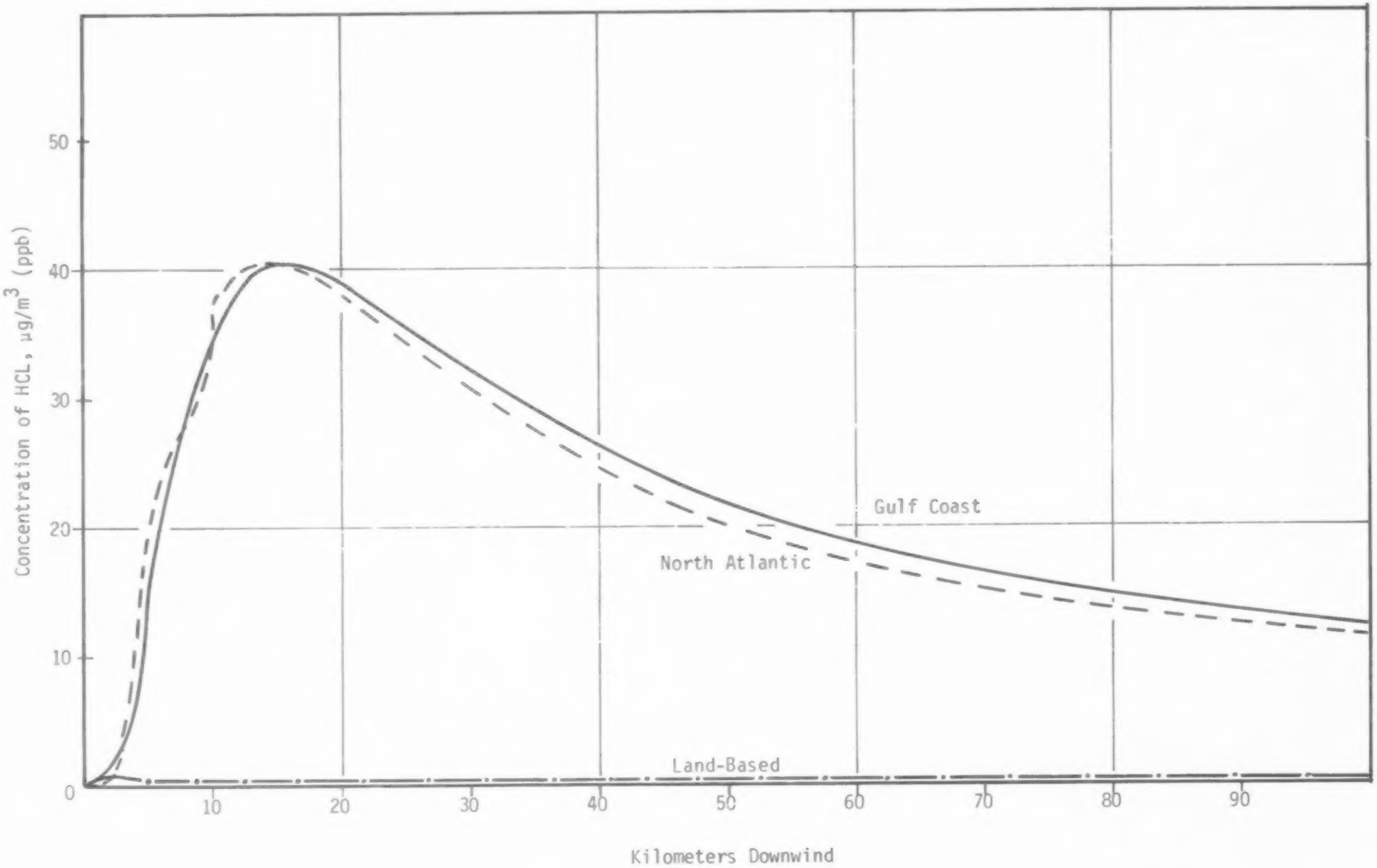

Figure E-4. Maximum downwind concentrations of HCl.

TABLE E-3. MAXIMUM SEA LEVEL CONCENTRATIONS IN THE AIR FOR THE GULF COAST SITE

DISTANCE DOWNWIND (METERS)	NORMALIZED EMISSION*	HCL (UG/M3)	2.4-D EQ (NG/M3)	SILVEX EQ (NG/M3)	TCDD (PG/M3)
500	.000	.000	.000	.000	.000
1000	.000	.000	.000	.000	.000
1500	.000	.002	.004	.002	.000
2000	.001	.135	.255	.127	.000
2500	.004	.965	1.822	.909	.000
3000	.012	2.901	5.475	2.732	.001
3500	.024	5.708	10.773	5.375	.002
4000	.037	8.896	16.792	8.377	.002
4500	.050	12.066	22.774	11.362	.003
5000	.062	14.982	28.279	14.108	.004
5500	.073	17.544	33.114	16.521	.005
6000	.082	19.728	37.236	18.577	.005
6500	.090	21.553	40.681	20.296	.006
7000	.096	23.056	43.519	21.712	.006
7500	.101	24.281	45.830	22.865	.006
8000	.105	25.268	47.692	23.794	.007
8500	.109	26.054	49.177	24.534	.007
9000	.111	26.673	50.345	25.117	.007
9500	.113	27.152	51.250	25.568	.007
10000	.145	34.807	65.699	32.777	.009
10500	.150	35.942	67.840	33.845	.010
11000	.154	36.910	69.667	34.757	.010
11500	.157	37.725	71.206	35.525	.010
12000	.160	38.403	72.486	36.163	.010
12500	.162	38.958	73.533	36.685	.010
13000	.164	39.402	74.372	37.104	.011
13500	.166	39.748	75.025	37.430	.011
14000	.167	40.006	75.512	37.673	.011
14500	.167	40.187	75.852	37.842	.011
15000	.168	40.298	76.063	37.947	.011
15500	.168	40.348	76.157	37.995	.011
16000	.168	40.345	76.150	37.991	.011
16500	.168	40.293	76.054	37.943	.011
17000	.168	40.200	75.878	37.855	.011
17500	.167	40.070	75.633	37.733	.011
18000	.166	39.908	75.327	37.580	.011
18500	.165	39.718	74.967	37.401	.011
19000	.165	39.503	74.562	37.199	.011
19500	.164	39.267	74.116	36.976	.010
20000	.163	39.012	73.635	36.736	.010
30000	.132	31.773	59.971	29.919	.008
40000	.109	26.172	49.400	24.645	.007
50000	.092	21.964	41.457	20.683	.006
60000	.079	18.896	35.667	17.794	.005
70000	.069	16.565	31.267	15.599	.004
80000	.061	14.736	27.815	13.877	.004
90000	.055	13.264	25.035	12.490	.004
100000	.050	12.053	22.750	11.350	.003

* Concentration the AR ($\mu g/m^3$) = normalized emission X mass emission rate (g/sec)

Concentrations are in micrograms (μg), nanograms (ng), and picograms (pg) per m^3 of air. On gram by weight basis, $\mu g/m^3$, ng/m^3, and pg/m^3 are roughly equivalent to parts per billion, parts per trillion, and parts per quadrillion, respectively.

TABLE E-4. MAXIMUM SEA LEVEL CONCENTRATIONS IN THE AIR FOR THE NORTH ATLANTIC SITE

DISTANCE DOWNWIND (METERS)	NORMALIZED EMISSION*	HCL (UG/M3)	2.4-D EQ (NG/M3)	SILVEX EQ (NG/M3)	TCDD (PG/M3)
500	.000	.000	.000	.000	.000
1000	.000	.000	.000	.000	.000
1500	.000	.007	.013	.007	.000
2000	.001	.280	.528	.264	.000
2500	.007	1.634	3.085	1.539	.000
3000	.018	4.364	8.237	4.110	.001
3500	.033	7.949	15.004	7.485	.002
4000	.049	11.739	22.157	11.054	.003
4500	.064	15.303	28.884	14.410	.004
5000	.077	18.436	34.798	17.360	.005
5500	.088	21.081	39.791	19.851	.006
6000	.097	23.256	43.696	21.900	.006
6500	.104	25.012	47.211	23.553	.007
7000	.110	26.409	49.846	24.868	.007
7500	.115	27.504	51.914	25.900	.007
8000	.118	28.351	53.512	26.697	.008
8500	.121	28.993	54.724	27.302	.008
9000	.123	29.469	55.622	27.750	.008
9500	.124	29.808	56.263	28.070	.008
10000	.155	37.195	70.205	35.025	.010
10500	.159	38.080	71.877	35.859	.010
11000	.162	38.803	73.241	36.540	.010
11500	.164	39.379	74.328	37.082	.011
12000	.166	39.825	75.170	37.502	.011
12500	.167	40.157	75.796	37.814	.011
13000	.168	40.388	76.233	38.032	.011
13500	.169	40.532	76.503	38.167	.011
14000	.169	40.598	76.629	38.230	.011
14500	.169	40.598	76.628	38.229	.011
15000	.169	40.539	76.517	38.174	.011
15500	.168	40.429	76.310	38.071	.011
16000	.168	40.275	76.020	37.926	.011
16500	.167	40.084	75.658	37.746	.011
17000	.166	39.859	75.235	37.534	.011
17500	.165	39.607	74.758	37.297	.011
18000	.164	39.331	74.236	37.036	.010
18500	.163	39.034	73.676	36.757	.010
19000	.161	38.720	73.083	36.461	.010
19500	.160	38.391	72.463	36.152	.010
20000	.159	38.051	71.821	35.831	.010
30000	.126	30.184	56.973	28.423	.008
40000	.102	24.509	46.260	23.079	.007
50000	.085	20.417	38.538	19.226	.005
60000	.073	17.472	32.979	16.453	.005
70000	.064	15.255	28.793	14.365	.004
80000	.056	13.526	25.531	12.737	.004
90000	.051	12.142	22.918	11.434	.003
100000	.046	11.009	20.780	10.367	.003

* Concentration in the air ($\mu g/m^3$) = Normalized emission X mass emission rate (g/sec)

Concentrations are in micrograms (μg), nanograms (ng), and picograms (pg) per m^3 of air. On a ppm by weight basis, $\mu g/m^3$, ng/m^3, and pg/m^3 are roughly equivalent to parts per billion, parts per trillion, and parts per quadrillion, respectively.

TABLE E-5. MAXIMUM GROUND LEVEL CONCENTRATIONS IN THE AIR FOR THE LAND-BASED INCINERATION ALTERNATIVE

DISTANCE DOWNWIND (METERS)	NORMALIZED EMISSION*	HCL (UG/M3)	2.4-D EQ (NG/M3)	SILVEX EQ (NG/M3)	TCDD (PG/M3)
500	.021	5.556	2.110	1.044	.000
1000	1.200	319.150	121.181	59.991	.017
1500	2.123	564.657	214.400	106.138	.030
2000	2.269	603.677	229.216	113.473	.032
2500	2.136	568.110	215.711	106.788	.030
3000	1.935	514.815	195.475	96.770	.027
3500	1.737	462.059	175.443	86.853	.025
4000	1.560	414.911	157.542	77.991	.022
4500	1.407	374.156	142.067	70.330	.020
5000	1.275	339.267	128.819	63.772	.018
5500	1.163	309.404	117.480	58.159	.017
6000	1.067	283.742	107.737	53.335	.015
6500	.983	261.564	99.316	49.166	.014
7000	.911	242.277	91.993	45.541	.013
7500	.847	225.397	85.583	42.368	.012
8000	.791	210.530	79.938	39.573	.011
8500	.742	197.361	74.938	37.098	.011
9000	.698	185.629	70.483	34.893	.010
9500	.658	175.124	66.495	32.918	.009
10000	.690	183.448	69.655	34.483	.010
10500	.650	172.992	65.685	32.517	.009
11000	.615	163.483	62.074	30.730	.009
11500	.582	154.807	58.780	29.099	.008
12000	.552	146.866	55.765	27.606	.008
12500	.525	139.578	52.998	26.236	.007
13000	.500	132.872	50.451	24.976	.007
13500	.476	126.685	48.102	23.813	.007
14000	.455	120.963	45.930	22.737	.006
14500	.435	115.661	43.916	21.741	.006
15000	.416	110.735	42.046	20.815	.006
15500	.399	106.150	40.305	19.953	.006
16000	.383	101.875	38.682	19.149	.005
16500	.368	97.880	37.165	18.399	.005
17000	.354	94.141	35.745	17.696	.005
17500	.341	90.636	34.415	17.037	.005
18000	.328	87.345	33.165	16.418	.005
18500	.317	84.249	31.989	15.836	.004
19000	.306	81.334	30.883	15.288	.004
19500	.295	78.585	29.839	14.772	.004
20000	.286	75.988	28.853	14.283	.004
30000	.165	43.968	16.695	8.265	.002
40000	.113	30.020	11.399	5.643	.002
50000	.084	22.281	8.460	4.188	.001
60000	.066	17.448	6.625	3.280	.001
70000	.053	14.183	5.385	2.666	.001
80000	.045	11.851	4.500	2.228	.001
90000	.038	10.113	3.840	1.901	.001
100000	.033	8.776	3.332	1.650	.000

* Concentration in the air ($\mu g/m^3$) = Normalized emission X mass emission rate (g/sec)

Concentrations are in micrograms (μg), nanograms (ng), and picograms (pg) per m^3 of air. On a ppm by weight basis, $\mu g/m^3$, ng/m^3, and pg/m^3 are roughly equivalent to parts per billion, parts per trillion, and parts per quadrillion, respectively.

E.5 MISCELLANEOUS CALCULATIONS

In Section 4.1.1 and earlier in Appendix E, worst case maximum emission rates of major combustion products were presented. These values were calculated as shown below. Assumptions used in these calculations were: 99.9% destruction efficiency; 0.5% conversion to carbon particles; liquid silvex feed rate of 5776 Kg/hr per incinerator; air feed rate of 70,000 dry, normal (25°C) m^3/hr per incinerator; and that the liquid silvex feed is identical to WEED-BE-GON ^{R} (21.4% butoxy propyl ester of 2,4-D (C_{15} H_2 O_4 Cl_2, 335.23 g/mol), 10.0% butoxy propyl ester of 2,4,5-TP (C_{16} H_{21} O_4 Cl_3, 383.70 g/mol), 74.02% carbon, 7.26% chlorine, and 0.58% ash), Reference 3. Molecular weights of 2,4-D and 2,4,5-TP acids are 221.04 and 269.51 g/mol, respectively.

E.5.1 2,4-D Equivalent

$$5776 \text{ Kg.hr}^{-1} \times 2 \times 0.001 \times 0.214 \times 221.04 \text{ g.mol}^{-1}/335.23 \text{ g.mol}^{-1} = 1.63 \text{ Kg/hr}$$

$$1.63 \text{ Kg.hr}^{-1} \times 10^6 \text{ mg.Kg}^{-1}/140{,}000 \text{ m}^3.\text{hr}^{-1} = 11.6 \text{ mg/m}^3$$

E.5.2 2,4,5-TP Equivalent

$$5776 \text{ Kg.hr}^{-1} \times 2 \times 0.001 \times 0.10 \times 269.51 \text{ g.mol}^{-1}/383.70 \text{ g.mol}^{-1} = 0.81 \text{ Kg/hr}$$

$$0.81 \text{ Kg.hr}^{-1} \times 10^6 \text{ mg.Kg}^{-1}/140{,}000 \text{ m}^3.\text{hr}^{-1} = 5.8 \text{ mg/m}^3$$

E.5.3 TCDD

$$5776 \text{ Kg.hr}^{-1} \times 2 \times 0.001 \times 10^6 \text{ mg.Kg}^{-1} \times 20 \times 10^{-9} = 0.231 \text{ mg/hr}$$

$$0.231 \text{ mg.hr}^{-1} \times 10^6 \text{ ng.mg}^{-1}/140{,}000 \text{ m}^3.\text{hr}^{-1} = 1.65 \text{ ng/m}^3$$

E.5.4 HCl

$$5776 \text{ Kg.hr}^{-1} \times 2 \times 0.0726 \times 36.461 \text{ g.mol}^{-1}/35.453 \text{ g.mol}^{-1} = 862.5 \text{ Kg/hr}$$

$$862.5 \text{ Kg.hr}^{-1} \times 10^3 \text{ g.Kg}^{-1}/140{,}000 \text{ m}^3.\text{hr}^{-1} = 6.16 \text{ g/m}^3$$

E.5.5 Particulates

$$5776 \text{ Kg.hr}^{-1} \times 2 \times 0.7402 \times 0.005 = 42.8 \text{ Kg/hr}$$

$$42.8 \text{ Kg.hr}^{-1} \times 10^6 \text{ mg.Kg}^{-1}/140{,}000 \text{ m}^3.\text{hr}^{-1} = 305 \text{ mg/m}^3$$

E.5.6 CO_2

$$5776 \text{ Kg.hr}^{-1} \times 2 \times 0.7402 \times 44.01 \text{ g.mol}^{-1}/12.01 \text{ g.mol}^{-1} = 31{,}334 \text{ Kg/hr}$$

$$31{,}334 \text{ Kg.hr}^{-1} \times 10^3 \text{ g.Kg}^{-1}/140{,}000 \text{ m}^3.\text{hr}^{-1} = 224 \text{ g/m}^3$$

E.5.7 CO

Given the assumptions stated above, the equilibrium mole fractions of CO and CO_2 at 1500°C are 9.87×10^{-5} and 0.117 (Table 10, Reference 3). Carbon monoxide concentration is calculated by proportion to carbon dioxide:

$31{,}334\ Kg.hr^{-1} \times (9.87 \times 10^{-5}/1.17 \times 10^{-1}) \times 28.01\ g.mol^{-1}/44.01\ g.mol^{-1}$
$= 16.8\ Kg/hr$

$16.8\ Kg.hr^{-1} \times 10^{6}\ mg.Kg^{-1}/140{,}000\ m^{3}.hr^{-1} = 120\ mg/m^{3}$

Oxidation of CO to CO_2 in the exhaust plume is neglected.

E.5.8 Maximum Downwind Concentration of CO

Table E-3 shows that maximum downwind concentrations of major combustion products occur at 15.5 Km. Maximum HCl concentration is 40.3 $\mu g/m^3$. Using equilibrium product distribution from Reference 3, the CO concentration can be calculated. From Table 10 of Reference 3, equilibrium mole fractions of CO and HCl are 9.87×10^{-5} and 3.72×10^{-3}, respectively, at 1500°C. Thus,

$CO,\ \mu g/m^{3} = 40.3\ \mu g.m^{-3} \times (28.01\ g.mol^{-1}/36.216\ g.mol^{-1}) \times 9.87 \times$
$10^{-5}/3.72 \times 10^{-3} = 0.82\ \mu g/m^{3}$

converting to ppmv

$(0.82\ \mu g.m^{-3} \times 10^{-6}\ g.\mu g^{-1}/28.01\ g.mol^{-1}) \times 0.022414\ m^{3}.mol^{-1} \times$
$298.15°K/273.15°K = 0.000704\ ppmv\ (0.7\ ppbv)$

The calculations for CO illustrated in Sections E.5.7 and E.5.8 based on equilibrium mole fractions can be performed for other combustion product species, such as SO_2, SO_3, Cl, etc.

E.5.9 Inorganic Particulates

The composition of the ash is unknown, consequently the metals present are unknown. The bulk of the metal content is likely to be sodium because alkaline hydrolysis is used in the synthesis of the silvex formulations. There are likely to be traces of metals of construction of synthesis and handling equipment, such as iron, manganese, nickel, and copper. For this purpose, all metal is assumed to be sodium and emitted as sodium chloride.

$5776\ Kg.hr^{-1} \times 2 \times 0.0058 \times 58.44\ g.mol^{-1}/22.99\ g.mol^{-1} = 170\ Kg/hr$

$170\ Kg.hr^{-1} \times 10^{3}\ g.Kg^{-1}/140{,}000\ m^{3}.hr^{-1} = 1.21\ g/m^{3}$

None of the foregoing calculations in Section E.5 take into account the volume of gases produced by combustion of the silvex formulations. Therefore, emission concentrations will be lower than those calculated above. Thus, these are conservative calculations.

E.6 CALCULATION OF LATERAL PLUME WIDTH - GULF COAST INCINERATION SITE

To calculate plume width at touchdown, the lateral dispersion term (given by $A(y,\sigma_y)$ in Appendix E.1) had to be taken into account. Equation 1 below shows the Gaussian dispersion equation in terms of normalized emissions at ground level. The entire bracketed term is nothing but the normalized emission given in Tables E-3 through E-5. The point on either side of the centerline where concentrations reached 30% of the centerline concentration was chosen as the edge of the plume. Touchdown was assumed to occur at 3000 meters downwind, where ground level concentrations begin to become "significant" (an arbitrary decision). Inserting the constants and restructuring equation 1 to solve for y, gives equations 2 and 3. The variable y is the laterial distance from centerline, and by symmetry the actual plume "width" will be two times y.

Note that results for the North Atlantic site will be essentially the same. Important parameters are given below:

- Touchdown occurs at 3000 meters
- $\sigma_y = 157.8704$
- $\sigma_z = 47.3684$
- Effective stack height, H = 166.2 meters

For ground level concentrations:

$$\frac{C(x,y,o)}{Q} = \left[\frac{1}{\pi u \sigma_y \sigma_z} \exp\left(\frac{-H^2}{2\sigma_y^2}\right)\right] \exp\left(\frac{-y^2}{2\sigma_y^2}\right) \qquad (1)$$

$$\frac{C(3000,y,o)}{Q} = (.012) \exp\left(\frac{-y^2}{2\sigma_y^2}\right) \qquad (2)$$

Define the edge of plume as point where concentration is 30% of centerline:

$$\frac{x}{.012} = \frac{30}{100}, \quad x = \frac{30(.012)}{100} = .0036$$

$$.0036 = (.012) \exp\left(\frac{-y^2}{2\sigma_y^2}\right) \quad \frac{y^2}{2\sigma_y^2}$$

$$\ln\left(\frac{.0036}{.012}\right) = \left[\frac{-y^2}{2\sigma_y^2}\right]$$

$$y = \sqrt{-2\sigma_y^2 \ln\left(\frac{.0036}{.012}\right)} \qquad (3)$$

$$y = 245 \text{ meters}$$

$$2y = 490 \text{ meters}$$

Therefore, plume width at touchdown will be approximately 490 meters.

E.7 CALCULATION OF WATER CONCENTRATIONS OF COMBUSTION PRODUCTS

This section presents calcualtions for sea water concentrations of 2,4-D and 2,4,5-T equivalents, HCl, and TCDD resulting from plume touchdown. It is assumed that 100% dissolution into the sea occurs.

In Appendix E.6, the width of the plume at touchdown was calculated to be 490 meters. Assuming the ship steams or drifts at a rate of 10 knots per hour (18.5 Km/hr), in 24 hours the plume impacts on an ocean area of 2.2×10^8 m^2:

$$18.5 \text{ Km.hr}^{-1} \times 24 \text{ hr} \times 490 \text{ m} = 2.2 \times 10^{8} \text{ m}^{2}$$

assuming a 2-m mixing depth, the volume of sea water in which one day's combustion products is diluted is:

$$8.2 \times 10^{8} \text{ m}^{2} \times 2 \text{ m} = 4.4 \times 10^{8} \text{ m}^{3} = 4.4 \times 10^{11} \ \ell$$

Now, assuming a 1-cm mixing depth, the volume of sea water in which one day's combustion products is diluted is:

$$2.2 \times 10^{8} \text{ m}^{2} \times 0.01 \text{ m} = 2.2 \times 10^{6} \text{ m}^{3} = 2.2 \times 10^{9} \ \ell$$

Using emission rates presented in Table E-2 for HCl, 2,4-D and 2,4,5-TP acids, and TCDD at 3 Km downwind, sea water concentrations are calculated below. Combustion air feed rate, Appendix E.5 is 140,000 m^3/hr.

- HCL

$$862.5 \text{ Kg.hr}^{-1} \times 24 \text{ hr}/4.4 \times 10^{11} \ell = 47 \ \mu\text{g}/\ell$$
$$862.5 \text{ Kg.hr}^{-1} \times 24 \text{ hr}/2.2 \times 10^{9} \ \ell = 9.4 \text{ mg}/\ell$$

- 2,4-D

$$1.63 \text{ Kg.hr}^{-1} \times 24 \text{ hr}/4.4 \times 10^{11} \ \ell = 89 \text{ ng}/\ell$$
$$1.63 \text{ Kg.hr}^{-1} \times 24 \text{ hr}/2.2 \times 10^{9} \ \ell = 18 \ \mu\text{g}/\ell$$

- 2,4,5-TP

$$0.81 \text{ Kg.hr}^{-1} \times 24 \text{ hr}/4.4 \times 10^{11} \ \ell = 44 \text{ ng}/\ell$$
$$0.81 \text{ Kg.hr}^{-1} \times 24 \text{ hr}/2.2 \times 10^{9} \ \ell = 9 \ \mu\text{g}/\ell$$

- TCDD

$$0.231 \times 10^{-6} \text{ Kg.hr}^{-1} \times 24 \text{ hr}/4.4 \times 10^{11} \ell = 13 \text{ fg}/\ell$$
$$\text{o}.231 \times 10^{-6} \text{ Kg.hr}^{-1} \times 24 \text{ hr}/2.2 \times 10^{9} \ \ell = 2.5 \text{ pg}/\ell$$

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2. Briggs, G.A., "Plume Rise," U.S. Atomic Energy Commission," TID-25075, November 1969.

3. Ackerman, D.G., R.J. Johnson, R.A. Orsini, B.L. Riley, and L.L. Scinto, "Operations Plan and Guidelines for the At-Sea Incineration of Liquid Silvex," EPA Contract No. 68-02-3174, Task 2, February 1980.

APPENDIX F

CALCULATIONS FOR CHARACTERIZATION OF SINGLE PASS SCRUBBER WASTEWATER

F. CALCULATIONS FOR CHARACTERIZATION OF SINGLE PASS SCRUBBER WASTEWATER

Assumptions used for this analysis are:

(1) All of the HCl formed during combustion is transferred into the scrubber wastewater. The maximum amount is assumed because this will be the worst case.

(2) Seventy-five percent of the water feed to the scrubber is retained. The remainder is lost by entrainment in the gas stream.

Analysis of scrubber wastewater quality at the Marquardt Company. Data were obtained from Reference 1.

Data:

Waste Incinerated - Hexachlorocyclopentadiene
Chlorine in Waste - 76.5%
Caustic Feed Rate - 23.8 liters/min
  - type of caustic - 12% NaOH - specific gravity - 0.95
Water Feed Rate - 60 liters/min
Waste Feed Rate - 52.8 kg/hr

Calculation of chloride content of scrubber wastewater:

Equation 1 $$\frac{(\%\ \text{Cl in waste})\ (\text{Waste feed rate})}{(75\%)\ (\text{scrubber solution feed rate})} = \text{Chloride Concentration in wastewater}$$

$$\frac{(.765)\ (52.8\ \text{kg/hr})\ \left(\frac{\text{hr}}{50\ \text{min}}\right)\ \left(1.0 \times 10^{6}\ \frac{\text{mg}}{\text{kg}}\right)}{(.75)\ (83.8\ \text{l/min})} = 10{,}711\ \text{mg/l}$$

Calculation of calcium or sodium ion concentrations in wastewater:

- Calculation of mass flow rate of solution
  23.8 liters/min x .95 kg/liter - 22.61 kg/min
- Calculation of NaOH flow rate at 12% of solution
  .12 x 22.61 kg/min - 2.71 kg/min NaOH

- Calculation of percent Na^+ ions at 57.5% of NaOH

  .575 x 2.71 kg/min = 1.56 kg/min

- Calculation of Na^+ ion concentration in wastewater

$$\frac{(1.56\ \text{kg/min})\ (1.0 \times 10^6\ \text{mg/kg})}{(.75)\ (83.8\ \text{liters/min})} = 24{,}821\ \text{mg/l}$$

Cl^- ions - 10,700 mg/liter
Na^+ ions - 24,800 mg/liter
TDS 35,500 mg/liter

Analysis of scrubber wastewater quality at Rollins Environmental Services.

Data obtained from Reference 2.

Date:

Waste Incinerated - Nitrochlorobenzene
Chlorine in Waste - 10.0%
Caustic Feed Rate - 8.5 liters/min
  - type of solution - 32% $Ca(OH)_2$ specific gravity 0.87
Water Feed Rate - 3200 liters/min
Waste Feed Rate - 1893 kg/hr

Calculation of chloride content in wastewater using Equation 1:

$$\frac{(.10)\ (1893\ \text{kg/hr})\ (\frac{\text{hr}}{60\ \text{min}})\ (1.0 \times 10^6\ \text{mg/kg})}{(.75)\ 3208\ \text{liters/min}} = 1.311\ \text{mg/l}$$

Calculation of calcium concentration in wastewater:

- mass flow rate of solution

  8.5 l/min x .87 kg/liter = 7.4 kg/min

- mass flow rate of $Ca(OH)_2$ at 32% of solution

  7.4 kg/min x .32 - 2.37 kg/min $Ca(OH)_2$

- mass flow rate of calcium ion at 54% of $Ca(OH)_2$

0.54 x 2.37 kg/min - 1.28 kg/min

- calculation of calcium concentration

$$\frac{1.28 \text{ kg/min} \times 1.0 \times 10^6 \text{ mg/kg}}{(.75)\ 3208 \text{ liter/min}} = 533 \text{ mg/liter}$$

Chloride ions	- 1,310 mg/liter
Calcium ions	- 530 mg/liter
TDS	- 1,840 mg/liter

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1. "Destroying Chemical Wastes in Commercial Scale Incinerators. Facility Report No. 1. The Marquardt Company," TRW Report to EPA, Contract No. 68-01-2966, NTIS No. PB 265541, 1976.

2. "Destroying Chemical Wastes in Commercial Scale Incinerators. Facility Report No. 6, Rollins Environmental Services," TRW Inc., and Arthur D. Little, Inc., Report to EPA, Contract No. 68-01-2966, NTIS No. PB 270897, 1977.